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## Journal of

# Oral Science & Rehabilitation

Journal for periodontology, implant dentistry, dental prosthodontics and maxillofacial surgery

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#### The two twin souls of research

In an ideal world, research in general, and dental research in particular, would answer all of the questions a clinician would formulate in order to better treat the final beneficiary of the research itself, the patient. Our journal has been designed from the very beginning to consider foremost the patient. In order to achieve this, several groups of researchers were invited to form part of the journal board, each group being represented by a clinician, whom I would call the "clinical soul" of the group.

However, clinical protocols alone can be interpreted in many different ways, even incorrectly, if not approached with the requisite background knowledge. In order to be able to yield a scientifically meaningful answer, clinical protocols must be validated under the supervision of highly trained researchers. For this reason, all of the groups that joined the journal constitute also an "analytic soul," in order to establish the methodology, lead the clinical study and interpret the results.

The two components of research, which I would call the two "souls of research," are linked to one another. Underestimating the importance of one of these two components, one of these two souls, or leaving one of them out would lead to an impoverishment of the value and benefit of any research results and therefore to the established goal remaining unfulfilled.

Dr. Luigi Canullo Associate Editor



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The Journal of Oral Science & Rehabilitation publishes original and highquality research and clinical papers in the fields of periodontology, implant dentistry, prosthodontics and maxillofacial surgery. Priority is given to papers focusing on clinical techniques and with a direct impact on clinical decision-making and outcomes in the above-mentioned fields. Furthermore, book reviews, summaries and abstracts of scientific meetings are published in the journal.

Papers submitted to the *Journal of Oral Science & Rehabilitation* are subject to rigorous double-blind peer review. Papers are initially screened for relevance to the scope of the journal, as well as for scientific content and quality. Once accepted, the manuscript is sent to the relevant associate editors and reviewers of the journal for peer review. It is then returned to the author for revision and thereafter submitted for copy editing. The decision of the editor-in-chief is made after the review process and is considered final.

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## Identification of *Staphylococcus aureus* at the internal and external implant surfaces in individuals with periimplant disease: A cross-sectional study

### Abstract

#### Objective

The objective of this study was to investigate the prevalence of *Staphylococcus aureus* (*S. aureus*) at internal and external dental implant surfaces in patients with periimplant disease.

#### Materials and methods

Samples for microbiological analysis were obtained from four types of sites in the following order: (1) the periimplant sulcular fluid (PISF) of each implant; (2) the gingival sulcus (GS) of the adjacent teeth; (3) the implant–abutment connection and abutment inner portions (IIP) of each implant; and (4) the oropharyngeal complex (OF)–oral, tongue and pharynx swabs were also collected.

Quantitative real-time polymerase chain reaction assays were carried out for total bacterial counts. The Kruskal–Wallis test was used to compare the *S. aureus* levels at the various sites.

#### Results

Mean bacterial counts of *S. aureus* were as follows:  $GS = 5.02 \times 10^2$ ; PISF = 0, IIP = 0 and OF = 0. A positive value was found for one out of the 35 sites for each group, but under the limit of quantification. For GS, one out of the 35 sites presented with a total bacterial count of 2.11 × 10<sup>4</sup>. No statistically significant differences were found among groups regarding site location (p = 0.40).

#### Conclusion

Within the limits of this study, *S. aureus* could not be quantified in the PISF and inside the IIP affected by periimplantitis.

#### Keywords

Periimplantitis, periimplant disease, microbiological analysis, opportunistic pathogens, implant connection, *S. aureus*.

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### Introduction

Dental implantology is a central part of modern dentistry concerned with the replacement of missing teeth in various clinical situations. In the past 30 years, the materials and methods of implant dentistry have undergone a substantial process of development and evolution. Implant surface, macrodesign and type of implantabutment connection have been found to be of major relevance to initial healing and long-term stability.<sup>1-3</sup> Since the number of implants placed has increased in the last ten years, optimal maintenance has become increasingly important.<sup>4, 5</sup> While in many cases, it has been reported that dental implants are a safe and predictable treatment method with high survival rates, they are not immune from biological and iatrogenic complications associated with improper treatment planning, surgical and prosthetic execution, or material failure, as well as maintenance problems.<sup>5</sup> Also, the biological complications of periimplant mucositis and periimplantitis, which may result in soft- and hard-tissue defects, have been suggested to be relevant for later marginal bone loss.6

Several approaches have been followed in seeking to understand the pathomechanism of periimplantitis. According to a consensus conference of the American Academy of Periodontology, bacterial colonization of the implant surface and the occurrence of bone loss indicate the point of no return in periimplantitis.<sup>7</sup> Periimplantitis is characterized by an inflammatory process around an implant that includes both soft-tissue inflammation and progressive loss of periimplant supporting bone. Periimplantitis occurs primarily as a result of overwhelming periodontal insult and subsequent immune response.7 The connection to periodontitis as an infectious disease with comparable symptoms and outcomes suggests that investigating the associated local bacteria is fundamental to establishing the pathomechanism of periimplantitis.

The implant surface may be colonized with different pathogens other than periodontal bacteria.<sup>8</sup> According to Albertini et al., opportunistic pathogens such as *Pseudomonas aeruginosa*, *Staphylococcus aureus* (*S. aureus*) and *Candida albicans* may be associated with implant failure.<sup>9</sup>

As suggested in an American Academy of Periodontology report, secondary diagnostic measures, that is, bacterial culturing, inflammatory markers and genetic factors, may be useful

in the diagnosis of periimplant disease.<sup>7</sup> According to Canullo et al., bacterial agglomerates around dental implants and their prosthodontic adjacent structures have been identified.<sup>10</sup> These results suggested that all of the connections were contaminated after five years of functional loading; thus, the implant-abutment connection design might influence bacterial activity levels qualitatively and quantitatively, especially inside the implant connection.<sup>10</sup> Furthermore, Cosyn et al. found that intracoronal compartments of screw-retained fixed restorations were heavily contaminated.<sup>11</sup> Further investigations have shown that the restorative margin is the principal pathway for bacterial leakage and contamination of abutment screws, and bacteria most likely pass from the periimplant sulcus through the implant-abutment and abutmentprosthesis interfaces.<sup>10</sup>

With the aim of identifying the pathogens that contribute toward the development of periimplantitis defects, different working groups have reported a cluster of bacteria, including *Treponema forsythia* and *S. aureus*, associated with periimplant disease.<sup>12</sup>

The presence of *S. aureus* as an opportunistic pathogen in the early stage of active periimplantitis in patients has also been confirmed by Mombelli and Décaillet.<sup>13</sup> In addition, Salvi et al. reported that detection or lack of *S. aureus* at implant sites at 12 weeks resulted in the highest positive (i.e., 80%) and negative (i.e., 90%) predictive values for the incidence of periimplantitis, respectively.<sup>14</sup> Moreover, Canullo et al. showed that *S. aureus* is present on the external and internal abutment surfaces if these are not cleaned before screwing.<sup>15</sup>

The aim of the present study is to investigate the prevalence of *S. aureus* in the oral cavity of patients with active periimplantitis. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.<sup>16</sup>

### Materials & methods

#### Study design

This cross-sectional study evaluated data collected from 51 consecutive, partially edentulous patients of both sexes, aged 18 or older (mean age of 54.2), who had been treated with a single implant-supported, cemented or screw-retained restoration functionally loaded for at least 12 months, with adjacent healthy teeth, but presenting signs of periimplant disease according to Mombelli and Décaillet.13 The patients were invited to participate and were enrolled after being given a detailed explanation of the study protocol. Written informed consent was obtained for each patient. All of the patients were recruited from the Department of Oral Surgery, University of Valencia, Spain, between September and December 2013. The investigation was conducted according to the principles outlined in the Declaration of Helsinki of 1975 for biomedical research involving human subjects, as amended in 2008. All patients were evaluated clinically and radiographically, and their medical histories were recorded. Bone volumes were analyzed using periapical radiographs.

The inclusion criteria were:

- presence of periimplant disease with a vertical bone defect of > 3 mm after implant integration according to Mombelli and Décaillet<sup>13</sup>
- age > 18
- no relevant medical conditions.

The exclusion criteria were:

- pregnancy or lactation
- known systemic disease or metabolic disorders (e.g., HIV) treated with medication detrimental to soft tissue and/or bone healing (e.g., high-dose steroid therapy, systemic treatment with tetracycline or tetracycline analogs, bone therapeutic levels of fluorides, bisphosphonates, medication affecting bone turnover, antibiotics for more than seven days or any investigational drug)-topical application of steroids and steroid application through inhalation were not exclusion criteria
- malignant diseases or other diseases treated with radiotherapy or chemotherapeutic agents (chemotherapy) during the past five years
- a history of head and neck radiation treatment owing to certain medical conditions
- a suspected allergy or incompatibility with any of the bone graft substitute components (calcium phosphates, PLGA, NMP)
- inability to comply with the protocol requirements, including severe alcohol or drug user
- involvement in any other clinical trial during the course of the present trial, or within a period of 30 days prior to its beginning or after its completion
- the prospective surgical field.

After full screening, 16 patients were to be excluded: 13 had taken systemic antibiotics during the three months prior to the microbiological sampling, two were pregnant, and one refused to participate. The final sample consisted of 35 individuals (20 male, 15 female) and 63 affected dental implants.

#### Microbiological sampling

Samples for microbiological analysis were obtained from four sites in each patient in the following order: (1) the periimplant sulcular fluid (PISF) of each implant; (2) the gingival sulcus (GS) of the adjacent teeth, used as control group; (3) the inner portions of the implant connection and the abutment of each implant (IIP); and (4) the oropharyngeal complex (OF). In all of the groups, the microbiological samples were taken using the GUIDOR Perio-Implant Diagnostic Kit (Sunstar Iberia, Sant Just Desvern, Spain), consisting of five sterile absorbent paper tips and an empty sterile 2 ml microtube.

Prior to collection of the subgingival plaque, supragingival plaque was eliminated from implants and teeth using a cotton tip, without penetrating the GS. OptraGate (Ivoclar Vivadent, Schaan, Liechtenstein) was used to retract the lips and cheeks completely and to ensure relative isolation. After light drying of the area with an air syringe, paper tips were inserted into the periimplant or periodontal sulci for 30 s. The samples from the inner surfaces of the implant-abutment complex were obtained after careful removal of both the restorations and the abutments, seeking to avoid contamination. One drop of RNA- and DNA-free water (Water Molecular Biology Reagent, W4502, Sigma-Aldrich, St. Louis, Mo., U.S.) was placed inside the implant connection and three paper tips were inserted for 30 s. The inner surface of the abutment was wet with a drop of RNA- and DNA-free water and smeared with two paper tips. The paper tips were placed into the microtubes and sent for microbiological analysis to the Institut Clinident laboratory (Aix-en-Provence, France) in the provided mailing envelopes. Finally, an oral environment analysis was performed using sterile cotton swabs collected from the cheeks, tongue, throat and pharynx of each patient.

After sample collection, the inner part of - acute abscesses localized in the proximity of the implants and the abutment-restoration complex were cleaned with a 5% chlorhexidine

Table 1

Sites	Positive sites/ number of sites	ТВС	Mean bacterial counts
GS	1/35	2.11 × 10 <sup>4</sup>	5.02 × 10 <sup>2</sup>
PISF	1/35	1 positive case, but below level of quantification	0
IIP	1/35	1 positive case, but below level of quantification	0
OF	1/35	1 positive case, but below level of quantification	0

GS: gingival sulcus of the adjacent teeth; PISF: periimplant sulcular fluid; IIP: inner parts of connection; OF: oropharyngeal complex.

solution in an ultrasonic bath for 10 min. Afterward, a new abutment screw was connected using a torque wrench (Torq Control, Anthogyr, Sallanches, France) until it reached a torque of 30 N cm, according to the manufacturer's instructions. In order to verify proper fit between the dental restoration and the implant, standardized digital periapical radiographs were taken using a dental radiographic film holder (Rinn Centrator Bite, DENTSPLY RINN, Elgin, Ill., U.S.) and the paralleling technique.

## Quantitative real-time polymerase chain reaction assays

Quantitative real-time polymerase chain reaction (PCR) assays were carried out for total bacterial counts (TBCs) for each target species, 17, 18 in a volume of 10 µL composed of 1× QuantiFast SYBR Green PCR (Qiagen, Hilden, Germany),  $2 \mu L$  of DNA extract, and  $1 \mu M$  of each primer. The species-specific PCR primers used in this study were provided by Institut Clinident and manufactured by metabion (Martinsried, Germany). Assays were carried out on the Rotor-Gene Q thermal cycling system (Qiagen) with the following program: for TBC, 95 °C for 30 s, followed by 40 cycles of 10 s at 95 °C, 10 s at 60 °C, and 35 s at 72 °C; for S. aureus, 95 °C for 5 min, followed by 40 cycles of 10 s at 95 °C, 10 s at 66 °C, and 35 s at 72 °C. A final melting curve analysis (70-95 °C in 1 °C steps for 5 s increments) was performed. Fluorescence signals were measured every cycle at the end of the extension step and continuously during the melting curve analysis. Serial dilutions of standard DNA, provided by Institut Clinident, were used in each reaction as external standards for absolute quantification of the target pathogen. Finally, the data were analyzed using Rotor-Gene Q Series Software (Qiagen).

#### Statistical analysis

Table 1

Investigated sites and bacterial counts.

The mean and standard deviations for TBCs at each inspected site (PISF, GS, IIP, OF) were recorded and analyzed according to a pre-established analysis plan. A bio-statistician with expertise in dentistry analyzed the data using statistical software (SigmaPlot, Version 13, Systat Software, San Jose, Calif., U.S.). Before running the statistical analysis, the TBCs for each site were transformed (log transformation  $[log_{10}]$ ) in an attempt to render less skewed distributions, making the data more interpretable and helping to meet the assumptions of inferential statistics. As the normality test failed, a nonparametric test (Kruskal–Wallis) was used. The level of significance was set at  $\alpha = 0.05$ .

#### Results

No implants were lost, and all of the prostheses were *in situ* at the time of examination. At the end of the study, just one site (out of 35) in the GS of the adjacent teeth presented a TBC of  $2.11 \times 10^4$ . The mean bacterial count of *S. aureus* was  $5.02 \times 10^2$ ; therefore, this value was taken as control. Conversely, in the PISF of each implant, the IIP and the OF complex, the mean bacterial counts of *S. aureus* were 0, with only one site (out of 35) positive, but below the level of quantification. The data are reported in **Table 1**. No statistically significant differences were found among groups regarding site location (Kruskal–Wallis test; p = 0.40).

#### Discussion

Currently, there are neither standardized antibiotic prophylactic regimens for dental implant place-

ment nor universally accepted treatment for periimplantitis. The treatment of infected implants is difficult and usually requires removal.<sup>18</sup> However, it has become clear that therapy of periimplant mucositis should be considered a preventive measure for the onset of periimplantitis. Completion of active periodontal therapy should precede implant placement in periodontally compromised patients.<sup>19</sup>

*S. aureus* is a facultative coccus and Gram-positive bacterium normally associated with surgical wounds in orthopedic patients.<sup>20</sup> Part of this can be explained by the impedance seen on cultured osteoblasts, with *S. aureus* surviving up to 48 h after internalization by those bone cells and still eliciting interleukin 6 and interleukin 8 responses,<sup>21</sup> which have pro-inflammatory effects and are involved in osteoclastogenesis<sup>22</sup> and foreign body reactions.<sup>23</sup> In addition, *S. aureus* has the ability to form a biofilm and lead to chronic infection.<sup>24</sup>

A retrospective study has demonstrated that patients capable of maintaining high immunoglobulin G antibody titers to *S. aureus* had successful implants compared with nonosseointegrated fixtures.<sup>25</sup>

In the present study, the lack of significance regarding the bacterial counts of S. aureus at IIP and PISF must be considered, since in vitro this pathogen has shown an affinity for titanium surfaces,<sup>26</sup> and two studies have related its levels to deep periimplant pockets with bleeding on probing.<sup>27, 25</sup> One study has demonstrated that the bacterial counts of S. aureus increase from 5% to 15% at implant sites 12 weeks after surgery.<sup>28</sup> However, another study pointed out that even after seven years of follow-up the presence of S. aureus at tooth sites could be indicative of the presence of the same pathogen at implant sites,25 while another study indicated that the lack of S. aureus at implant sites after 12 weeks demonstrated a high negative predictive value after 12 months.<sup>29</sup> More recently, an article demonstrated that regardless of health status, periodontal and periimplant sites harbored S. aureus cells, being the highest load of all six species analyzed.<sup>30</sup>

### Conclusion

Within the limits of this study, *S. aureus* could not be quantified inside and around dental implants in detectable limits. However, clinicians must bear in mind that, in the early stage of healing, this pathogen can influence the immune response and lead to periimplant bone loss.

#### **Competing interests**

The study was supported by Sweden & Martina (Due Carrare, Italy), which paid for the kits, and by the Institut Clinident, which performed the analysis free of charge. The authors declare that they have no competing interests related to this study.

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## Influence of the position of implants placed immediately into extraction sockets: An experimental study in dogs

### Abstract

Objective

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The objective of this study was to evaluate the influence of implant positioning within an extraction socket on the depth of the implant at the time of surgery and on the buccal supracrestal exposure of the implant surface after healing.

#### Materials and methods

Eight Labrador dogs were used. Their fourth mandibular premolars were first hemisectioned and the distal roots removed. The distal alveoli were subsequently prepared bilaterally at the apex for implant placement. The implants were placed tilted either in contact with the buccal (buccal position; B-sites) or the lingual (lingual position; L-sites) walls of the alveoli. After four months, biopsies were collected and processed for histomorphometric analysis.

#### Results

The implants were found to be approximately 1 mm deeper at the L-sites than at the B-sites. At the buccal aspect, a vertical resorption of 1.6  $\pm$  1.9 mm at the B-sites and of 0.4  $\pm$  0.7 mm at the L-sites was observed. The absolute vertical lingual bone resorption was 0.6  $\pm$  0.5 mm and 0.7  $\pm$  0.4 mm at the B- and L-sites, respectively. The percentage of bone-to-implant contact was similar at both sites, as well as buccolingually, and ranged between 31.2% and 35.2%. The width of the buccal bony ridge was larger at the L-sites compared with the B-sites. The periimplant mucosa was wider and located more coronally at the L-sites compared with the B-sites.

#### Conclusion

At implants placed immediately into extraction sockets, smaller buccal exposure above the bone crest occurred when they were placed tilted lingually instead of buccally. The implants placed lingually resulted in a deeper position within the extraction socket compared with those placed buccally.

#### Keywords

Animal study, bone healing, extraction socket, defect, implant dentistry, osseointegration, histology, IPIES.

#### Introduction

After tooth extraction, the immediate placement The research protocol was submitted to and apof an implant into an alveolus is considered a predictable procedure, even though a higher loss of implants has been reported.<sup>1</sup> Moreover, it has been shown that an implant placed into an extraction socket will not avoid bone resorption at the coronal aspect of the walls of the alveolus.<sup>2,3</sup>

One of the most important aspects to be considered is the position of the implant within the extraction socket in relation to the buccolingual walls of the alveolus. It has been shown that a buccal placement will produce, after healing, higher supracrestal exposure of the implant at the buccal aspect compared with a lingual positioning.<sup>4-7</sup> This may be explained by the higher resorption of the buccal bone plates compared with the lingual bone plates during healing after tooth extraction so that a slope will be formed, being higher at the lingual aspect compared with the buccal aspect.<sup>8</sup> This, in turn, means that the closer the implant is to the lingual aspect and the farther from the buccal aspect, the lesser the exposure of the implant body above the bony crest will be.

Owing to anatomical, functional and esthetic reasons, in a clinical situation, the axis of an implant placed into an extraction socket will be more lingually located compared with the tooth axis. This is explained by the presence of residual defects between the implant body and the walls of the extraction socket that will be larger and more likely to occur at the buccal aspect compared with the lingual aspect.<sup>2</sup> When an implant is placed into an extraction socket, the recipient site will generally be prepared with a lingual bodily displacement, maintaining more or less the same axis of the alveolus. However, it has been suggested that, owing to the different projection, if the axis of the implant is tilted in a lingual direction, the implant will be located deeper within the extraction socket than it would have been had the same axis as that of the alveolus been maintained,<sup>9</sup> even though the margin will be located at the same level as the buccal bone crest.

The concept of implant positioning needs to be further clarified. Hence, the aim of the present experiment is to evaluate the influence of implant positioning within an extraction socket on the depth of the implant at the time of surgery and on the buccal supracrestal exposure of the implant surface after healing.

### Materials & methods

proved by the ethics committee for animal research at the Universidade Estadual Paulista (Araçatuba, Brazil). Eight Labrador dogs were included in the study. The animals had a mean weight of approximately 30 kg and a mean age of 2 years and were housed in kennels on concrete runs at the university's field laboratory with free access to water and moistened balanced dog food.

#### Clinical procedures

At each surgery, the animals were first preanesthetized with Acepran (0.05 mg/kg; Univet-Vetnil, São Paulo, Brazil) and then anesthetized with Zoletil (10 mg/kg; Virbac, São Paulo, Brazil) and Xilazina (1 mg/kg; Cristália, São Paulo, Brazil), supplemented with ketamine (1/4 of the dose of 10 mg/kg; Cristália, São Paulo, Brazil). Before the surgical procedure, the pulp of the mesial roots of the fourth mandibular premolars was removed on both sides of the mandible, and the root canals were filled with gutta-percha and root canal cement (Mtwo, Endopocket, Epfill, Sweden & Martina). The crowns were afterward restored with composite (Adonis, Sweden & Martina).

The surgical procedure began with an incision performed within the sulcus. The flaps were elevated and the buccal and lingual alveolar bone plates were exposed. The fourth premolars were first hemisectioned and the distal roots removed, together with the corresponding portion of the crowns. The distal alveoli were subsequently prepared at the apex for implant placement. However, randomly, the drill was tilted buccally at one site and lingually at the other. Implants 11.5 mm in length and 3.5 mm in diameter (Alvim CM, Neodent, Curitiba, Brazil) and with a rough surface (sandblasted and acid etched) were placed with the shoulder flush with the buccal bone (Figs. 1a & b). At one site, the implant was placed in a buccal position (B-sites), in contact with the buccal wall of the alveolus, while in the opposite jaw, the implant was placed lingually (L-sites), in contact with the lingual wall of the alveolus (Figs. 2a & b).

Using a #15 UNC probe (Hu-Friedy, Chicago, Ill., U.S.), the horizontal and vertical dimensions of the remaining buccal or lingual

#### Implant positioning within extraction sockets

#### Figs. 1a & b

Clinical buccal view. Implants placed into the distal alveoli of the fourth premolars in a (a) lingual and (b) buccal position. Note that the implant in the lingual position was deeper in relation to the lingual bone crest compared with the implant placed buccally.



Figs. 2a & b

Clinical occlusal view. Implants placed into the distal alveoli of the fourth premolars in a (a) lingual and (b) buccal position.

> defects were measured, as well as the vertical distance between the top of the bony crest and the implant shoulder at the lingual aspect. Abutments of appropriate length were attached to the implants and sutures were applied to allow nonsubmerged healing.

After completion of the surgery, the animals were given a vitamin compound (Potenay, Fort Dodge Animal Health, Campinas, Brazil), an anti-inflammatory and analgesic drug (Banamine, Schering-Plough Animal Health, Campinas, Brazil) and an antibiotic (Pentabiótico, Fort Dodge Animal Health, Campinas,

Brazil). Three times per week for the first two weeks after surgery, the wounds were inspected for clinical signs of complications and the implant abutments were cleaned and disinfected with chlorhexidine. Afterward, cleaning was performed three times per week. The animals were euthanatized four months after the surgery, with overdoses of thiopental (Cristália, Itapira, Brazil) and then perfused with a fixative (4% formaldehyde solution) through the carotid arteries. Fig. 3



#### Histological preparation

Individual blocks containing the implant and the surrounding hard and soft tissue were collected from the mandible and fixed in a 4% formaldehyde solution. The specimens were subsequently dehydrated in a series of graded ethanol solutions and finally embedded in resin (LR White, hard grade, London Resin, Reading, UK). The blocks were cut along the buccolingual plane using a diamond band saw fitted in a precision slicing machine (EXAKT 300, EXAKT Advanced Technologies, Norderstedt, Germany) and then reduced to a thickness of approximately 60 µm using a cutting and grinding device (EXAKT 400, EXAKT Advanced Technologies). The histological slides were stained with Stevenel's blue and alizarin red and examined under a standard light microscope for histometric analysis.

#### Histological evaluation

Under an Eclipse Ci microscope (Nikon, Tokyo, Japan), connected to a computer through a video

camera (Nikon Digital DS-Fi2, Nikon), the following landmarks were identified **(Fig. 3)**: the implant shoulder (IS), the top of the adjacent bony crest (C), the most coronal point of contact between the bone and implant (B), the top of the mucosal margin (PM), the surface of the implant at the top of the threads (S), the outer contour of the bony crest (OC) and the outer contour of the periimplant mucosa (OM). The following measurements were performed using NIS-Elements software (Version 4.1; Nikon, Tokyo, Japan) under 40× magnification: the vertical distance between IS and C, IS and B, as well as PM and IS. PM–B was calculated from the data available.

Under 40× magnification, the width of the alveolar bony crest was measured from S to OC at the IS level (0 mm) and then apical to it at each subsequent millimeter, up to 5 mm (**Fig. 3**). The width of the periimplant mucosa was measured at the IS level (0 mm) and then up to 3 mm coronal to the abutment surface and up to 3 mm apical to it, from S. Under 100× magnification, the percentage of bone-to-implant contact (BIC%) was evaluated from the IS to the apical extension of the implant, both buccally and lingually.

#### Data analysis

Mean values and standard deviations, as well as the 25<sup>th</sup>, 50<sup>th</sup> (median) and 75<sup>th</sup> percentiles, were calculated for each outcome variable. Differences between buccally (B-sites) and lingually (L-sites) positioned implants were analyzed using the Wilcoxon signed-rank test for paired observations using IBM SPSS Statistics for Windows (Version 19.0; IBM Corp., Armonk, N.Y., U.S.). The vertical level of the bony crest and osseointegration (IS–C and IS–B) were the main outcome variables. The level of significance was set at  $\alpha$  = 0.05.

### Results

In one animal, a fracture of the buccal wall of the alveolus occurred during extraction and the animal was excluded entirely from analysis. No artifacts were generated during histological processing, nor were any tissue blocks destroyed. Hence, the B- and L-sites yielded n = 7. In the text, mean values  $\pm$  standard deviations are reported, and in the tables, the medians and the 25<sup>th</sup> and 75<sup>th</sup> percentiles are included too.

Landmarks used for histomorphometric analyses: IS: implant shoulder; C: top of the adjacent bony crest; B: most coronal point of contact between the bone and implant; PM: top of the mucosal margin; S (dashed green line): the surface of the implant at the top of the threads; OC (dashed yellow line): the outer contour of the bony crest; OM (dashed blue line): the outer contour of the periimplant mucosa.

#### Table 1

Clinical dimensions (mm) of the residual bone defects after implant placement (n = 7). Mean values (standard deviations) and medians (25<sup>th</sup>; 75<sup>th</sup> percentiles) are reported.

#### Fig. 4

Ground sections illustrating the histological healing after four months at the B-sites (20× magnification; Stevenel's blue and alizarin red stain).

#### Fig. 5

Ground sections illustrating the histological healing after four months at the L-sites (20× magnification; Stevenel's blue and alizarin red stain).

	Residual vertical depth		Residual ho	rizontal gap	C–IS	
	Buccal Lingual		Buccal	Lingual	Buccal	Lingual
<b>B</b> -sites	0.0	4.8 (1.3)	0.0	1.2 (0.4)	0.0	0.4 (0.3)
	0.0	5.0 (4.3; 5.0)	0.0	1.0 (1.0; 1.3)	0.0	0.5* (0.3; 0.5)
L-sites	4.3 (1.3)	0.0	1.2 (0.3)	0.0	0.0	1.5 (0.8)
	5.0 (3.0; 5.0)	0.0	1.0 (1.0; 1.5)	0.0	0.0	1.0* (1.0; 1.8)

C top of the adjacent bony crest; IS: implant shoulder. No statistically significant differences (ho < 0.05) were found between the lingual defects at B-sites and the buccal defects at L-sites for vertical depth and horizontal gap. \*p < 0.05 between B-sites and L-sites for C–IS at buccal and lingual aspects.



	IS	-C	Absolute	bone loss	IS-B		C–B Residual vertical defect		S-C Residual horizontal defect	
	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual
B-sites	1.6 (1.9)	0.1 (0.7)	1.6 (1.9)	0.6 (0.5)	1.9 (1.8)	1.7 (1.8)	0.3 (0.3)	1.6 (1.4)	0.2 (0.3)	1.2 (0.5)
	0.7 <sup>*,**</sup> (0.7; 1.4)	0.0** (-0.4;0.4)	0.7 <sup>*, **</sup> (0.7; 1.4)	0.7 (0.3; 0.9)	1.5 (0.9; 1.7)	0.9 (0.9; 1.6)	0.1 <sup>*, **</sup> (0.0; 0.4)	1.4** (0.7; 1.9)	0.1** (0.0; 0.5)	1.2 <sup>*,**</sup> (0.8; 1.5)
L-sites	0.4 (0.7)	-0.8 (0.9)	0.4 (0.7)	0.7 (0.4)	1.4 (0.7)	1.0 (0.8)	1.1 (0.9)	1.6 (1.2)	0.4 (0.2)	0.5 (0.4)
	0.5 <sup>*, **</sup> (0.1; 0.8)	-0.6** (-1.2; -0.2)	0.5* (0.1; 0.8)	0.7 (0.5; 1.1)	1.6 (1.0; 1.8)	0.8 (0.4; 1.7)	1.2* (0.4; 1.7)	1.2 (0.8; 2.5)	0.4 (0.3; 0.5)	0.3* (0.3; 0.7)

IS: implant shoulder; C: top of the adjacent bony crest; B: most coronal point of contact between the bone and implant; S: surface of the implant at the top of the threads.

p < 0.05 between B-sites and L-sites. p < 0.05 between buccal and lingual aspects.

	BIC%		PM-C		PM-B		PM–IS		
	Buccal	Lingual	Total	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual
B-sites	31.2 (23.2)	34.9 (22.5)	33.1 (22.3)	3.9 (0.4)	2.8 (0.5)	4.2 (0.5)	4.4 (1.4)	2.3 (1.7)	2.7 (0.8)
	13.4 (13.0; 52.6)	34.0 (16.6; 47.3)	23.9 (14.8; 49.9)	3.9* (3.7; 4.2)	2.8* (2.6; 3.1)	4.0 (3.9; 4.6)	3.8 (3.5; 4.7)	2.8** (2.5; 3.3)	2.6 (2.3; 3.2)
L-sites	35.2 (19.7)	31.6 (34.9)	35.0 (16.6)	4.2 (0.4)	2.5 (0.4)	5.1 (1.1)	4.3 (1.4)	3.8 (0.7)	3.3 (1.1)
	30.7 (20.9; 47.7)	35.2 (25.6; 46.3)	33.0 (23.3; 47.0)	4.2* (4.1; 4.2)	2.5* (2.4, 2.8)	5.3* (4.3; 5.8)	3.7* (3.3; 5.4)	3.5** (3.3; 4.1)	2.9 (2.8; 3.5)

PM: top of the mucosal margin; C: top of the adjacent bony crest; B: most coronal point of contact between the bone and implant; IS: implant shoulder. \*p < 0.05 between buccal and lingual aspects. \*p < 0.05 between B-sites and L-sites.

Table 3

Table 1





#### Clinical evaluation (Table 1)

After implant placement, residual marginal bone defects were observed that were  $4.8 \pm 1.3$  mm deep and  $1.2 \pm 0.4$  mm wide at the lingual aspect of the B-sites and  $4.3 \pm 1.3$  mm deep and  $1.2 \pm 0.3$  mm wide at the buccal aspect of the L-sites. The distance between the lingual bone crest and the implant shoulder was  $0.4 \pm 0.3$  mm at the B-sites and  $1.5 \pm 0.8$  mm at the L-sites, the difference being statistically significant (p = 0.017). This indicates that, despite the implant margin being placed flush with the buccal bone crest at both the B- and L-sites, the implant was approximately 1.1 mm deeper with respect to the lingual bony crest when positioned lingually within the extraction socket compared with buccal positioning.

#### Histological evaluation

Ground sections showing examples of healing at the B-sites are illustrated in **Figure 4** and of healing at the L-sites in **Figure 5**.

#### Hard-tissue dimensions (Table 2; Fig. 6)

IS-C at the buccal aspect was  $1.6 \pm 1.9$  mm at the B-sites and  $0.4 \pm 0.7$  mm at the L-sites. The difference was statistically significant. At the lingual aspect, IS-C was  $0.1 \pm 0.7$ mm and  $-0.8 \pm 0.9$  mm at the B- and L-sites, respectively. When the absolute instead of the relative values were taken into account, the bone crest resorption at the lingual aspect was  $0.6 \pm 0.5$  mm at the B-sites and  $0.7 \pm 0.4$  mm at the L-sites. None of the differences between the B-sites and L-sites for relative and absolute values at the lingual aspect were statistically significant.



The width of the buccal bone ridge (OC-S) was larger at the L-sites compared with the B-sites. However, the difference was statistically significant only at the 1 mm level **(Fig. 7)**.

#### Soft-tissue dimensions (Table 3; Fig. 6)

PM–C and PM–B at the buccal aspect were  $3.9 \pm 0.4$  mm and  $4.2 \pm 0.5$  mm at the B-sites and  $4.2 \pm 0.4$  mm and  $5.1 \pm 1.1$  mm at the L-sites. None of the differences were statistically significant. The periimplant mucosa was located more coronally at the L-sites ( $3.8 \pm 0.7$  mm) compared with the B-sites ( $2.3 \pm 1.7$  mm), the difference being statistically significant. The width of the periimplant mucosa was greater at the L-sites compared with the B-sites. The differences were statistically significant at all levels considered (**Fig. 7**).

#### Table 2

Histological hard-tissue dimensions (mm; n = 7). Mean values (standard deviations) and medians (25<sup>th</sup>; 75<sup>th</sup> percentiles) are reported.

#### Table 3

Histological soft-tissue dimensions (mm) and BIC% (n = 7). Mean values (standard deviation) and medians (25<sup>th</sup>; 75<sup>th</sup> percentiles) are reported.

#### Fig. 6

Graphic showing the mean values of the dimensions of the periimplant hard and soft tissue. IS: implant shoulder; C: top of the adjacent bony crest; B: most coronal point of contact between the bone and implant; PM: top of the mucosal margin.

#### Fig. 7

Graphic showing the mean values of the alveolar softand hard-tissue width at the buccal aspect after four months of healing. The continuous lines represent the width of the tissue at the L-sites, and the dotted lines represent the width at the B-sites. Red and blue lines represent the mucosal and bone widths, respectively. IS: implant shoulder.



## Discussion

The first aim of the present study was to evaluate the influence of implant positioning within an extraction socket on the depth of the implant. The apex of the alveolus was used as apical point for preparation and the drills were tilted toward either the buccal or the lingual aspects. No bodily displacements were applied. The implants were, consequently, placed in contact with the buccal or the lingual walls of the extraction sockets. Clinically, the lingual positioning of the implant is mainly achieved by a bodily displacement. However, a slight angulation of the implant may be applied toward the lingual bone wall when necessary for anatomical or prosthetic reasons. In the present experiment, the final position was obtained by changing the angulation in relation to the axis of the extraction socket. The procedure applied in the present experiment exaggerated the difference in angulations of the implants between the two groups, B- and L-sites, allowing the limits to be tested. It was shown that placing the implant lingually resulted in the implant shoulder being deeper with respect to the lingual bone crest compared with a buccal position, even though the implant margin was placed at the same level as the buccal bone crest. This was due to the rotation of the projection that occurred when the surgeon placed the implant flush with the buccal wall of the extraction socket, as described previously in another experiment in dogs.9 From a clinical perspective, if a lingual tilting of the implant is included in the procedure, a deeper positioning of the implant can be expected compared with an implant placed following the axis of the alveolus or in a buccal position. This should be taken into account if the buccal bone crest of the alveolus is used as the reference level to judge the depth of the recipient implant site.

In the present experiment, the placement of an implant in a lingual position resulted in reduced supracrestal exposure of the implant compared with a buccal positioning. This is in complete agreement with other studies that showed similar results.<sup>4–7</sup> In an experiment in dogs,<sup>4</sup> implants placed immediately into extraction sockets were placed in the center of the alveoli at the control sites, and placed lingually and 0.8 mm deeper at the test sites. The supracrestal exposure of the implants was higher at the centrally compared with the lingually positioned implants. In another experiment in dogs,<sup>6,7</sup> the implants were placed in a central position of the ex-

traction sockets of third premolars and lingually in the alveoli of fourth premolars. After three months of healing, higher supracrestal exposure was found at the implants placed in the center of the alveoli. These results were also validated by a multivariate multilevel analysis on implants placed into sockets immediately after tooth extraction.<sup>5</sup> The reason for this outcome may be explained by the fact that the buccal wall of the extraction socket undergoes higher resorption than the lingual wall does.<sup>8, 10</sup> The healing at an implant placed into an extraction socket immediately after tooth extraction will be affected by this resorption. The more buccal the implant placement, the greater the supracrestal exposure of the buccal surface of the implant will be. This assumption has been further corroborated by other experimental studies on implants placed immediately into extraction sockets.<sup>11, 12</sup> In these experiments in dogs, wide implants with the same coronal dimensions as the extraction sockets were placed on one side, and implants narrower than the extraction sockets were used on the other side. In the latter, a gap resulted between the buccal bone wall and the implant. Higher buccal bone resorption was observed at the wide compared with the narrow implants.

Factors such as the thickness of the buccal bone and the size of the horizontal defects present at the time of implant placement may influence ridge alterations.<sup>13</sup> It was shown that buccal bone crests of ≤1mm and residual buccal gaps of ≤1mm presented higher vertical and horizontal resorption compared with buccal bone crests of >1mm and residual buccal gaps of >1mm.<sup>13</sup> This may indicate that the distance between the outer contour of the bone crest at the buccal aspect and the surface of the implant plays the most important role. This, in turn, means that the closer the implant is placed into an extraction socket with respect to the outer contour of the bone crest, the greater the supracrestal exposure of the buccal surface of the implant will be.

After four months of healing, the top of the bone crest at the lingual aspect was located 0.1 mm below the implant shoulder at the B-sites and 0.8 mm above the implant shoulder at the L-sites. However, this does not mean that higher resorption occurred at the lingual crest at the B-sites compared with the L-sites. In fact, owing to the different angulation of the implants with respect to the axis of the alveolus, the implants at the L-sites were located deeper with respect to the lingual bone crest at the time of placement compared with the implants at the B-sites. When the original position of the implants was taken into account, similar absolute values of lingual bone crest resorption were found.

At the time of placement, defects were present opposite the implants. At the B-sites, lingual defects with mean values of 1.6 mm in depth and 1.2 mm in width were still present after four months of healing. At the L-sites, residual defects were also present at both the buccal (1.1 mm) and the lingual (1.6 mm) aspects. At the buccal aspect, the defects lay entirely between the implant surface and the bone wall, while at the lingual aspect, the residual defects were opposite the implant surface in the apical part and opposite the abutment in the coronal part. In a clinical situation, the implant is generally placed in a lingual position and residual defects may be present after healing. However, their presence may not be detected clinically if they are very narrow (≤ 0.5 mm). BIC% was similar at the buccal and lingual aspects, both at the B- and the L-sites, demonstrating that the position of the implants within the extraction sockets did not affect the degree of osseointegration. The lingual position affected the height of the periimplant mucosa, which was more coronal with respect to the implant shoulder at the L-sites compared with the B-sites.

## Conclusion

In conclusion, at implants placed immediately into extraction sockets, smaller buccal exposure above the bone crest will occur when implants are placed in a lingual compared with a buccal position. Moreover, implants placed lingually will be located deeper within the extraction sockets compared with those placed buccally when the implants are tilted lingually or buccally, respectively, in relation to the axis of the alveolus.

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## Clinical and histological evaluation of a flapless socket preservation procedure: A prospective single cohort study

### Abstract

#### Objective

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The objective of this study was to evaluate the dimensional changes to hard and soft tissue after a flapless ridge preservation procedure in the posterior area of the jaw.

#### Materials and methods

Patients requiring tooth extraction and subsequent implant restoration were considered eligible for the study. Cortico-cancellous porcine bone and a resorbable collagen membrane were used to graft fresh extraction sockets, and sutures were used to stabilize the membrane. Four months after the ridge preservation procedure, all of the sites were re-entered, bone cores were harvested for histological and analysis, and implants were placed. The width of keratinized gingiva, the thickness of the buccal bone wall, and the horizontal and vertical bone dimensional variation were measured at baseline and after four months.

#### Results

Thirty-seven patients were enrolled in the study. After four months, the amount of vertical bone loss was  $0.2\pm0.7$  mm for mesial sites,  $1.1\pm0.9$  mm for buccal sites,  $0.2\pm0.8$  mm for distal sites and  $0.9\pm0.9$  mm for palatal/lingual sites. The thickness of the buccal bone wall was found to be correlated to the horizontal bone loss. The keratinized gingiva showed a mean increase in the occlusal direction of  $1.8\pm0.7$  mm. Newly formed bone could be observed around the grafting material in the histological analysis, even though residual grafted particles were still present.

#### Conclusion

In this study, we observed that the flapless ridge preservation procedure was effective in maintaining an adequate bone architecture, which allows implant placement; moreover, this procedure improved the amount of keratinized tissue. The exposure of the resorbable collagen membrane to the oral cavity did not jeopardize the healing process or the quality of the newly formed bone.

#### Keywords

Ridge preservation, flapless, collagen membrane, post-extraction socket, biomaterial.

#### Introduction

The treatment of extraction sockets is a daily challenge in clinical practice. Several changes to the bone dimensions occur after tooth extraction, since the alveolar bone is a tooth-dependent tissue.<sup>1</sup> Bone modeling and remodeling are unavoidable during healing of an extraction socket.<sup>2-4</sup> A number of studies have pointed out that most of the resorption occurred during the first three months, although dimensional changes have been observed up to one year after a tooth extraction.<sup>5-7</sup>

The changes to the alveolar ridge after tooth extraction showed the greatest amount of bone loss in the horizontal dimension and a concomitant loss of vertical ridge height, which has been reported to be more evident at the buccal level.<sup>5,8,9</sup> The morphological changes at the extraction sites resulted in narrow and short edentulous alveolar ridges; moreover, the alveolar crest margin tended to shift lingually/palatally according to a specific pattern. Some clinical data has indicated that the alveolar crest tends to move two-thirds lingually/palatally from the original buccal edge; thus, the amount of resorption at the midfacial point doubled the bone loss at the distal and mesial points.<sup>8</sup>

A recent consensus report assessed that it is important to distinguish between the various procedures used to preserve the alveolar ridge.<sup>3</sup> Ridge preservation techniques include all procedures that preserve the ridge volume within the soft- and hard-tissue envelope existing at the time of extraction.<sup>3</sup> A ridge preservation procedure is recommended in the following circumstances: when implant placement is not possible at the time of tooth extraction, when the patient is not available for immediate implant placement, when primary stability of the implant cannot be guaranteed, and when treating adolescent patients.<sup>3</sup> The use of various techniques and biomaterials has been proposed over time; however, no significant differences have been shown between the various biomaterials, although collagen alone has been proved to be unable to counteract tissue changes after tooth extraction.<sup>5, 4, 10–12</sup>

An ideal grafting biomaterial should be resorbable, in order to allow replacement with new bone while balancing the speed of resorption and the volumetric stability. The use of a grafting material with a high resorption rate results in the complete disappearance of the biomaterial after

a few months. This has been observed for calcium sulfate after three months and for a polylactide-polyglycolide acid sponge after six months.13 Nevertheless, high resorption of the biomaterial is not always desirable, especially in anatomical sites where vertical and horizontal volumetric shrinkage are expected. The use of collagenated cortico-cancellous porcine bone has shown positive results in socket preservation procedures after three months.<sup>14, 15</sup> In fact, histological and histomorphometric analyses gave positive results in terms of newly formed bone, absence of inflammatory cells and signs of active resorption of the grafted particles,<sup>14</sup> suggesting that collagenated cortico-cancellous porcine bone could be suitable for ridge preservation procedures.

A full-thickness flap elevation during tooth extraction may have accounted for slightly more pronounced bone remodeling compared with a flapless extraction, owing to the interruption of the blood vessels.<sup>9, 16, 17</sup> Soft-tissue primary closure was originally considered necessary for proper incorporation of the graft.<sup>2, 9, 18, 19</sup> The early exposure of the membrane to the oral cavity was thought to jeopardize the effectiveness of tissue augmentation;<sup>16, 20</sup> these findings pointed out the importance of achieving full closure and primary healing when the socket is grafted and covered with a membrane.<sup>2</sup>

Experimental models have reported less pronounced bone remodeling when a flapless approach was used for socket preservation,<sup>21</sup> but there is still no consensus on the effect of the elevation of a full-thickness flap. However, one study found no significant difference between the flapless and flapped approach.<sup>22</sup> A recent study observed the effects of a full-thickness flap elevation on the regenerative process of socket preservation procedures.<sup>14</sup> The comparison between the flapped and the flapless procedures showed no significant differences in the histological and histomorphometric analysis, in terms of newly formed bone, residual graft and marrow space rates, suggesting that the exposure of the collagen membrane did not jeopardize the regenerative process.<sup>14</sup>

The aim of the current study was to evaluate the clinical outcomes of a ridge preservation technique with a flapless approach in the posterior area of the jaw. Dimensional changes to the hard and soft tissue at fresh extraction sites treated with the use of cortico-cancellous porcine bone and a resorbable collagen membrane were evaluated over the observation period. Bone cores were also harvested at the time of implant placement for histological analysis.

#### Materials & methods

#### Study population and design

Patients were recruited from the consultation clinic at the Istituto Stomatologico Toscano, Versilia general hospital, University of Pisa, Lido di Camaiore, Italy, from January 2013 to January 2014. The study was approved by the ethics committee of the Versilia general hospital according to the principles outlined in the Declaration of Helsinki on clinical research involving human subjects. All of the patients received a thorough explanation of the study and completed a written informed consent form prior to being enrolled in the trial.

Forty patients requiring extraction of at least one premolar or one molar and a subsequent implant-supported restoration who were 18 years old or older and able to sign an informed consent form were eligible for inclusion in this trial. One patient showed complete loss of the buccal bone plate immediately after the extraction and two patients did not return for the follow-up examinations. Consequently, these patients were excluded, and 37 patients were included in the study. The patients enrolled in the study had a mean age of  $40.5 \pm 13.5$  and an age range of between 20 and 61.

The exclusion criteria were:

- history of systemic disease that would contraindicate oral surgical treatment
- long-term nonsteroidal anti-inflammatory drug therapy
- intravenous and oral bisphosphonate therapy
- lack of the occluding teeth
- absence of adjacent teeth
- complete loss of a bone wall
- surgical sites in the esthetic area
- uncontrolled periodontal disease
- unwillingness to return for the follow-up examination
- smoking of more than ten cigarettes per day subjects who smoked fewer than ten cigarettes per day were requested to stop smoking before and after surgery; however, their compliance could not be monitored.

Patients who were included in the study were accurately evaluated by examining clinical aspects and periapical and panoramic radiographs. Moreover, data were collected for each patient, including age, sex, smoking habits, and indications for tooth extraction based on both clinical and radiographic examinations, tooth location and the presence or absence of adjacent teeth.

After the consent form had been signed, all of the patients underwent at least one session of scaling and root planing prior to the extraction procedures in order to provide a more favorable oral environment for wound healing. All of the patients underwent the tooth extraction and the ridge preservation procedure at baseline. Four months after tooth extraction, all of the sites were re-entered, bone biopsies were taken and implants were placed.

#### Surgical treatment

All of the patients received antibiotic therapy (2 g amoxicillin or 600 mg clindamycin, if allergic to penicillin) 1h before the surgery and continued to take the antibiotic postoperatively (1 g amoxicillin or 300 mg clindamycin) b.i.d. for four days. All of the patients rinsed for 1 min with a 0.2% chlorhexidine mouthwash prior to the surgery (as well as b.i.d. for the following three weeks) and were treated under local anesthesia using lidocaine with 1:50,000 epinephrine. All of the surgical procedures were performed by two surgeons (AB, FA), who received training during a one-week session before beginning the study. The training included calibration for the surgical and follow-up procedures, as well as the handling of any complications. All of the patients were treated with the same surgical technique and periotomes were used around every tooth treated. Moreover, ultrasound bone surgery (PIEZOSURGERY, mectron, Italy) was performed where necessary in order to avoid buccolingual movements of the tooth, thus preventing damage to or a full fracture of the buccal bone wall.

The extraction sockets were thoroughly curetted and irrigated with a sterile saline solution. Cortico-cancellous porcine bone (mp3, OsteoBiol, Tecnoss Dental, Pianezza, Italy) was lightly condensed inside the socket and a resorbable collagen membrane (Evolution, Osteo-Biol, Tecnoss Dental) was placed over it in order to cover the socket completely. The membrane, which was left exposed to the oral cavity, was stabilized with 4-0 silk sutures, and soft-tissue



Preoperative radiograph. Tooth #25 was to be extracted because of nontreatable root

Example of the probe used for the clinical measurements.

Resin stent positioned on the experimental site in order to standardize the clinical measurements.

Occlusal view of the experimental site showing the preoperative situation.

Post-extraction socket.

Cortico-cancellous porcine bone grafted inside the socket.

Sutures used to stabilize the graft and the collagen membrane.

Occlusal view of the experimental site four months after the ridge preservation procedure.

healing was by secondary intention, since no flap was raised (Figs. 1-8). All of the patients were instructed to continue the antibiotic therapy, and 550 mg naproxen sodium tablets were prescribed as an anti-inflammatory (b.i.d. as necessary). Removable prostheses, if present, were not used for at least three weeks and then adjusted before reuse.

The surgical re-entry was performed four months after the first-stage surgery. Bone biopsies were collected and implants (BL CT, Intra-Lock, Boca Raton, Fla., U.S.) were placed (Fig. 9). Of the implants placed, 61% had a diameter of 5 mm and 39% of 4 mm. Adjunctive augmentation procedures at the time of implant placement were necessary in 7% of the experimental sites.

#### Fig. 9

Implant placement.

Fig. 10 Implant uncovering.

## Fig. 11

Radiographs three months after implant placement.

**Fig. 12** Final prosthesis.



Three months after placement, the implants were uncovered and manually tested for stability (Fig. 10). At this time, impressions were taken using a polyvinyl siloxane impression material (Flexitime, Heraeus Kulzer, Hanau, Germany) and customized resin impression trays. Final ceramic restorations were made and seated, and all of the patients were enrolled in an oral hygiene program, with a recall visit every three months (Figs. 11& 12).

#### Clinical parameters

Several clinical parameters were measured at each time of examination, including at baseline and four months after the ridge preservation procedure. The clinical parameters taken into consideration in the present study were

- width of keratinized gingiva, measured at the midfacial point of the buccal aspect using a Williams periodontal probe (at baseline, the measure corresponded to the distance between the mucogingival junction and the gingival margin; at the four-month examination, it was the distance between the mucogingival junction and the highest part of the edentulous crest)
- thickness of the buccal bone, measured immediately after tooth extraction using a surgical caliper

- vertical bone changes, registered with a surgical stent positioned on the adjacent teeth and measured with a Williams periodontal probe soon after the tooth extraction and at the time of implant placement (four months after the first-stage surgery)
- horizontal bone changes, measured with a Williams periodontal probe soon after the tooth extraction and after four months.

#### Histological analysis

Bone biopsies were collected during the secondstage surgery. The bone cores were immediately stored in a 10% buffered formalin solution and sent to the Department of Medical and Oral Sciences and Biotechnologies, "Gabriele d'Annunzio" University of Chieti-Pescara, Chieti, Italy. The samples were then processed to obtain thinground sections, using the Precise 1 Automated System (Assing, Rome, Italy). The specimens were dehydrated in a graded series of ethanol rinses and embedded in a glycol methacrylate resin (Technovit 7200 VLC, Heraeus Kulzer, Wehrheim, Germany). After polymerization, the specimens were sectioned along the longitudinal axis with a high-precision diamond disc at approximately 150 µm and ground down to approximately 30 µm. Three slides were obtained from each specimen, stained with acid fuchsin and

Figs. 9 & 10

Figs. 11 & 12

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Age (years)	40.5 ± 13.5 (20 ↔ 61)
Males	15
Females	22
Experimental sites	37
Molars	25
Premolars	12
Mean buccal bone thickness at baseline (mm)	2.1±0.7 (1↔3)

Table 1

Demographic data.

#### Table 2

Dimensional changes four months after the ridge preservation procedure.

### Table 2

Clinical parameters	Site	Baseline (mm)	4 months (mm)	Difference (mm)	<b>P-value</b> (baseline vs. 4 months)
	Mesial	11.4 ± 1.1 (10 ↔ 14)	11.6 ± 1.3 (10 ↔ 15)	-0.2 ± 0.7 (-2 ↔ +1)	0.0367
Vertical	Buccal	12.8 ± 1.2 (10 ↔ 15)	13.9 ± 1.1 (11 ↔ 16)	-1.1 ± 0.9 (-3 ↔ +1)	0.000000145 (1.45 × 10 <sup>-7</sup> )
bone changes	bone changes Distal	11.2 ± 1.1 (10 ↔ 15)	11.5 ± 1.1 (10 ↔ 14)	-0.2 ± 0.8 (-2 ↔ +1)	0.071
	Lingual/ palatal	2.0 ± 1.4 (9 ↔ 14)	12.9 ± 1.4 (10 ↔ 15)	-0.9 ± 0.9 (-3 ↔ +1)	0.00000843 (8.43 × 10 <sup>-6</sup> )
Horizontal bone changes		9.2 ± 1.3 (7 ↔ 12)	7.6 ± 1.2 (5 ↔ 10)	-1.6 ± 0.5 (-3 ↔ -1)	< 0.0001 (4.5 × 10 <sup>-20</sup> )
Width of keratinized gingiva		2.8 ± 0.9 (1 ↔ 5)	$\begin{array}{c} 4.6 \pm 0.8 \\ (3 \leftrightarrow 6) \end{array}$	1.8 ± 0.7 (1 ↔ 4)	< 0.0001 (5.7 × 10 <sup>-17</sup> )

toluidine blue, and examined in transmitted and polarized light using a transmitted light microscope (Leitz Laborlux, Leitz, Wetzlar, Germany). One well-trained examiner (GI), who was not involved in the surgical treatment, evaluated the histological results.

#### Statistical analysis

Descriptive statistical analysis was performed on all of the data collected, with SPSS software (Version 6.1.2; SPSS, Chicago, Ill., U.S.). Pearson's chi-squared test was performed for categorical ured at baseline and ranged from 1.0 to 3.0 mm, data. The *p*-value for significance was set at 0.05. All of the measurements in the text and tables are given as medians and interquartile ranges (the difference between the 75<sup>th</sup> and 25<sup>th</sup> percentiles).

## Results

A single-tooth extraction with a flapless ridge preservation procedure was performed for each of the 37 patients enrolled in the study, with a cedure, the vertical bone loss was  $0.2 \pm 0.7$  mm total of 25 molars and 12 premolars that needed

to be extracted owing to fracture (42%), nontreatable endodontic lesions (14%) and severe root decay (44%). All of the surgical procedures performed in this study were successful and no complications were observed during the healing period (Table 1).

At baseline, the mean width of keratinized gingiva was  $2.8 \pm 0.9$  mm (range of 1.0 - 5.0 mm). After four months, it was 4.6 ± 0.8 mm, showing an increase of 1.8 ± 0.7 mm, which was statistically significant (p = 0.0001).

The thickness of the buccal bone was measwith a mean of 2.1 ± 0.7 mm (Table 1). The mean width of the alveolar crest at baseline was  $9.2 \pm 1.3$  mm, and after four months, it was 7.6  $\pm$  1.2 mm; therefore, the mean width of the alveolar crest showed a decrease of  $1.6 \pm 0.5$  mm (p < 0.0001). The comparison between the thickness of the buccal bone wall and the width of the alveolar crest indicated that the correlation between the two values was statistically significant (Table 2).

Four months after the ridge preservation profor mesial sites,  $1.1 \pm 0.9$  mm for buccal sites,



#### Fig. 13

Newly formed bone around the grafting material. No inflammatory cells or foreign body reaction was observed.

 $0.2\pm0.8$  mm for distal sites and  $0.9\pm0.9$  mm for palatal/lingual sites. The dimensional changes were statistically significant for all of the sites **(Table 2)**.

The histological analysis performed on the retrieved bone cores found that the granules of grafted bone were still present, even though new trabecular bone could be observed in all of the specimens. Osteocytic lacunae could be seen on the particles' surfaces, and newly formed bone was observed inside some of the resorption areas of the biomaterial. Vascular growth close to the newly formed bone was also evident, and no inflammatory cells or foreign body reaction around the biomaterial granules was observed (**Fig. 13**).

#### Discussion

Ridge preservation techniques have been proposed in order to reduce the bone volume shrinkage that follows a tooth extraction, since several studies have reported resorption of both vertical and horizontal dimensions.<sup>1,6,7,23</sup> The use of various biomaterials and techniques has been proposed over time, but there is still no evidence to indicate the best choice. In the present study, 37 single-tooth extractions and the subsequent flapless ridge preservation procedures were performed. Cortico-cancellous porcine bone and a resorbable collagen membrane were used in all of the cases, and several clinical parameters

were measured at the tooth extraction and after four months, including width of keratinized gingiva, thickness of the buccal bone wall, and changes to the vertical and horizontal dimensions.

A minimally invasive tooth extraction technique, with preservation of the socket walls during the surgery, helps to maintain the architecture of the alveolar crest, <sup>1,4</sup> even if bone remodeling is not completely avoidable.9 A flapless surgical technique was chosen in our study because, even though some studies have not reported any significant differences between a flapped and a flapless surgical technique, <sup>5, 24</sup> Van der Weijden et al. assert that the elevation of a full-thickness flap is believed to compromise the blood supply, limiting the future regenerative potential.<sup>23</sup> Furthermore, the use of a flapless technique has been demonstrated to be less traumatic for both hard tissue-avoiding interruption of the blood flow-and soft tissue-preserving the keratinized gingiva.<sup>25, 15, 26</sup> The exposure of the collagen membrane and the soft-tissue closure by secondary intention seemed not to jeopardize the bone healing, and 100% of the ridge preservation procedures were successful. The width of the keratinized gingiva gained 1.8 ± 0.7 mm after four months. These results correspond to those of other studies that used a similar surgical protocol.14

The evaluation of the clinical parameters in this study confirmed the efficacy of this surgical procedure in counteracting the soft- and hardtissue shrinkage after a tooth extraction: both the vertical and horizontal dimensions showed a minimal decrease. In particular, the vertical dimension lost  $0.2\pm0.7$  mm at the mesial sites,  $1.1\pm0.9$  mm at the buccal sites,  $0.2\pm0.8$  mm at the distal sites and  $0.9\pm0.9$  mm at the palatal/lingual sites after four months. These results are in keeping with those reported in a recent systematic review that compared the outcomes after tooth extractions with and without ridge preservation procedures.<sup>27</sup> In the case of the ridge preservation procedures, the vertical bone changes ranged from a gain of  $1.3\pm2.0$  mm to a loss of  $0.62\pm0.51$  mm, with follow-up times ranging from three to nine months.<sup>27</sup>

In the current study, the ridge preservation procedures in all of the experimental sites were successful, and implants were placed after four months, with further augmentation procedures being necessary only in 7% of the cases at the time of implant placement. Moreover, bone cores were harvested for the histological analysis at the time of implant placement. Corroborating the findings of other studies,<sup>28, 29</sup> this study found that the cortico-cancellous porcine bone was effective in maintaining the architecture of post-extraction sockets and demonstrated signs of active resorption at the same time. lezzi et al. examined the use of various biomaterials and performed histological and histomorphometric analyses after six months.<sup>28</sup> Among the different grafting materials, cortico-cancellous porcine bone gave rise to a rim of osteoblasts with signs of active bone matrix deposition; in some areas, bone apposition was observed directly on the particles' surfaces.<sup>28</sup> Similarly, the biomaterial used in this study showed a great percentage of newly formed bone. No inflammatory cells or foreign body reaction was observed in the bone samples, but new bone tissue and blood vessel growth. Active resorption signs were evident, since osteocytic lacunae were observed at the surface of the biomaterial granules. As found by another study,<sup>29</sup> collagenated porcine bone was demonstrated to be resorbable, showing active resorption signs on the surface of the particles.

Another study investigated the effect of the exposure of the resorbable membrane to the oral cavity on bone healing, comparing a flapped and a flapless approach.<sup>14</sup> The percentages of newly formed bone, residual graft particles and marrow spaces were similar for the two groups, suggesting that the exposure of the collagen membrane had no detrimental effect on the regenera-

tive process.<sup>14</sup> Similarly, in our study, the secondary intention healing seemed not to affect the bone quality, as seen in the bone cores. The findings of this study support the hypothesis that secondary intention healing and exposure of the collagen membrane do not jeopardize bone regeneration, but improve the amount of keratinized gingiva. The ridge preservation technique was demonstrated to be effective in maintaining an adequate bone architecture, allowing the subsequent implant placement without adjunctive augmentation procedures in the majority of the cases

Further studies are necessary to evaluate the influence of early exposure of the membrane on the formation of new bone and on the integration of the grafting material overtime. Furthermore, a longer follow-up period could be useful in order to monitor the success of the biomaterial and the quality of the newly formed bone.

### Conclusion

Within the limits of this prospective cohort study, ridge preservation showed adequate regeneration of the bone and stability of the facial soft-tissue level. The flapless ridge preservation procedure maintained the horizontal and vertical bone dimensions, improving the amount of keratinized tissue. The exposure of the resorbable collagen membrane to the oral cavity seemed not to jeopardize the healing process or the quality of the newly formed bone.

#### **Competing interests**

The authors declare that they have no conflict of interests related to this study.

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## Review of the arterial vascular anatomy for implant placement in the anterior mandible

## Abstract

#### Objective

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The placement of implants in the anterior region of the mandible is not free of risk and can even sometimes be life-threatening. The aim of this article is to review the anatomy of the anterior mandible regarding the placement of implants in this region.

#### Materials and methods

An anatomical study was conducted in cadavers to analyze the various anatomical structures of the anterior region of the mandible. A literature review was also undertaken.

#### Results

The sublingual and submental arteries are the main supply of the sublingual region. These arteries are usually located at a safe distance from the alveolar ridge, but in cases of severe atrophy or anatomical variations, there may be an increased risk of damage during the placement of dental implants and serious complications may arise.

#### Conclusion

The injury of the vessels in the floor of the mouth could lead to severe complications. Implant surgery in the anterior mandible should be planned with 3-D radiographic imaging to establish accurate 3-D positioning of the implant.

#### Keywords

Anatomy, arteries, mandible, hemorrhage, dental implants.

#### Introduction

Knowledge of the topographic anatomy of the mandibular region is very important in implant dentistry. Severe, life-threatening complications can occur after dental implant placement in the mandible, especially in the anterior region. In the case of arterial vascular trauma in the floor of the mouth during implant placement in the mandibular anterior region, surgeons should be prepared to manage a severely compromised oropharyngeal airway.<sup>1</sup>

The number of complications associated with implantology has risen owing to the increasing number of implants being placed. An electronic search performed in the MEDLINE (PubMed) and Embase databases with the search term "dental implants" indicated that the number of articles related to dental implants increases every year. Worthington wrote, "The number of practitioners performing implant surgery has increased dramatically over the last fifteen years. As confidence is gained, they tend to accept increasingly challenging cases and it is to be expected that the incidence of problems and complications will increase. Serious problems and complications may result from inadequate treatment planning, some from careless instrumentation, and some from lack of appropriate precautions."<sup>2</sup> Some important early complications after dental implantation may be neurological,<sup>3,4</sup> infections<sup>5</sup> and hemorrhages,<sup>6,1,7</sup> Neurological complications are the most frequent (8.5%),<sup>4</sup> followed by infections (1.8%),<sup>8</sup> and severe, life-threatening hemorrhagic complications are the most rare, with only 15 cases reported in the literature.<sup>6</sup>

Although severe immediate hemorrhagic complications are infrequent, the mechanical pressure from sealed bleeding spaces adjacent to the upper airway may become life-threatening extremely quickly.<sup>1</sup> Therefore, these are the most serious complications, especially when they occur in the anterior region of the mandible. Laceration of the inferior alveolar artery can lead to severe bleeding, but the compression by the implant itself can stop the hemorrhage. The floor of the mouth is not a closed cavity like the canal of the inferior alveolar nerve; therefore, if bleeding occurs, the blood collects in the supramylohyoid space, pressing the tongue to the palate. Thus, perforation of the lingual cortical plate in the anterior region of the mandible can cause uncontrollable

bleeding of the sublingual artery, which requires in-hospital treatment.<sup>6</sup> The practitioner must have an extensive knowledge of the anatomy of the surgical field to avoid this complication.

This paper highlights the essential anatomical details that must form part of the practitioner's knowledge in order to perform dental implant surgery in the anterior mandible with maximum safety and minimal risk.

## Materials & methods

A study of the anatomical body structures located in the anterior mandible and floor of mouth was performed. The cadavers used were donated by the University of Valencia (Valencia, Spain). An intravascular perfusion with colored latex was performed for better discrimination of the vessels. The tissue was dissected with the blunt technique principally—closed scissors were inserted into the connective tissue and then opened. The structures were recorded photographically.

A literature review was conducted to assess the anatomy of the anterior mandible, through a search in electronic databases, namely MED-LINE (PubMed), Embase and the Cochrane Library. Boolean operators and truncation were used for the search. The search terms used were "(anatomy OR vessel\* OR muscle OR artery) AND anterior AND mandible." The inclusion criteria were case reports, anatomical studies on cadavers or radiographic studies of the anatomy of the floor of the mouth and the anterior mandible, performed in humans. The exclusion criterion was anticoagulated patients.

#### Results

## Bony anatomy and musculature of the sublingual region

Among the soft tissues surrounding the mandible are the floor of the mouth (made of up the sublingual region and the tongue itself), and the mental and genial areas. The sublingual region is limited below by the mylohyoid muscle, laterally by the hyoglossus, genioglossus and geniohyoid muscles, above by the mucosa of the floor of the mouth, and anteriorly by the body of the mandible **(Fig. 1)**.





mental spine (Figs. 1 & 2). The digastric fossa, from which the anterior digastric muscle originates, is located on the mandible's inner side, near the lower edge in the paramedian location (Fig. 3).

#### Sublingual artery

The sublingual artery follows a medial course to the mandible within the sublingual gland and supplies the mylohyoid muscle **(Fig. 4)**. It is at the level of this muscle that the sublingual artery issues branches that anastomose with the submental artery.<sup>11</sup> The artery ends in the mental spine.

#### Submental artery

This artery is a branch of the facial artery. It passes together with the mylohyoid nerve along the inferior surface of the homonymous muscle to the anterior region, where it supplies the anterior digastric muscle **(Fig. 5).** At this anterior level, the perforating branches of the submental artery pierce the mylohyoid muscle to anastomose with perforating branches of the sublingual artery.<sup>12</sup>

#### Vascular anastomosis

There are many anastomoses of the arteries involved in the sublingual region. An anastomosis found between the lingual and the submental ar-

#### Fig. 2

Anatomical structures of the sublingual space. Sagittal plane. shaped and tilted toward the lingual area. The mandibular symphysis is the medial area of the mandible that results from the endochondral ossification and the subsequent mergence of Meckel's cartilage in the 24<sup>th</sup> week of intrauterine life.<sup>9</sup> At that time, the musculature forms, affecting the development and subsequent growth of the mandible.<sup>10</sup> In this region, the mental spines stand out where the *quadratus labii inferioris* muscle forms. The superior and inferior mental spines are located on the mandible's inner side **(Fig. 2)**. The genioglossus muscle originates from the superior mental spine, while the geniohyoid muscle originates from the inferior

The mandible in the symphyseal area is drop-



teries runs along the bottom flange of the mandibular body and through the mylohyoid muscle (Fig. 6). Anastomoses between both sublingual contralateral arteries in the symphysis are frequent too (Fig. 7).

In summary, the mandibular symphyseal area is supplied by multiple vascular structures from different origins and presents a variability dependent on the anastomosing relationships established by the terminal branches of these structures.<sup>13–15</sup>

## Discussion

The sublingual region is well vascularized, with several anastomoses that can impair hemostasis if bleeding occurs.<sup>7</sup> Treatment can be uncomfortable for the patient, so the priority is to prevent trauma occurring through good anatomical knowledge of the area and proper planning of the surgery.

Regarding the bony anatomy and musculature of the anterior mandible, the mental spines are located in the mandible's inner side. Some studies highlight its morphological variability, for example the variability in the distance from the mental spine to the inferior border of the mandible or to apices of the mandibular incisors.<sup>16</sup> The genioglossus and geniohyoid muscles originate from the mental spines, so this variability may increase the risk of damage to these structures when dental implants are placed in this area.

The digastric fossa is located on the mandible's inner side, near the lower edge in the paramedian location. Therefore, an injury caused by piercing of the mandibular cortical bone, for example when placing a dental implant, may affect different muscles depending on whether the implant preparation is in the medial or paramedian location in relation to the mandibular symphysis.<sup>17</sup>

Three arteries supply this anatomical region: (a) the sublingual artery, which is a branch of the lingual artery; (b) the submental artery, which is a branch of the facial artery; and (c) the chin artery, which is the terminal branch of the inferior alveolar artery. The lingual and facial arteries are

#### Fig. 3

Musculature of the mandible and sublingual artery piercing the mandibular lingual plate.

#### Fig. 4

Anatomical photograph of the arterial supply of the floor of the mouth.

#### Fig. 5

Course of the facial and submental arteries.

#### Fig. 6

Location of the sublingual and submental arteries. (Modified from Kalpidis and Setayesh<sup>1</sup> with permission from the American Academy of Periodontology.)
Fig. 7

Anastomosis of the sublingual arteries.

#### Fig. 8

Mandibular medial lingual canal.



Fig. 8



both branches of the external carotid artery and the inferior alveolar artery is a branch of the maxillary artery.<sup>11</sup>

Katsumi et al. classify the arterial supply to the floor of the mouth into four types.<sup>18</sup> In Type I, the sublingual region is supplied by the sublingual artery. In Type II, it is supplied by the sublingual and submental arteries. In Types III and IV, it is supplied by the submental artery (the difference between the last two being that in Type III the deep lingual artery-which sup-

artery, and in Type IV it comes from the submental artery).

The sublingual artery is the main supply of the sublingual region. Anatomical and radiographic studies have identified lingual vascular canals in the mandible where the sublingual artery pierces the mandibular lingual cortical plate (Figs. 6 & 8).<sup>19-21</sup> The frequency of lateral lingual canals in the area of the mandibular incisors varied between 33.1% and 100.0% and in the area of the canines between 69.0% and 80.0% of the cases.<sup>19–21</sup> The location of the lingual canals coincided with the most frequent sites of clinically important bleeding during implant placement. The diameter of the canals was on average 1.2 mm, which is enough to produce severe sublingual bleeding.<sup>22</sup> Katakami et al. observed anastomoses between the lateral lingual canals and the inferior alveolar canal in 20.1% of the cases.  $^{\rm 6,\,21}$ 

The inferior alveolar artery provides an intraosseous blood supply to the symphyseal area and the mandibular incisors by an incisal branch that runs through the incisal canal. This canal has an average length of 19.78 mm from the mental foramen toward the midline.<sup>13</sup> The mental artery branches from the inferior alveolar artery inside the mandibular canal and exits the mandible through the mental foramen. It plies the tongue-originates from the lingual supplies the chin and anastomoses with its



counterpart on the opposite side and the submental and inferior labial arteries.<sup>12</sup>

There are several anastomoses between the major arteries supplying the floor of the mouth and the sublingual region. This fact is important because bleeding is more difficult to control whenever anastomoses are present. The following anastomoses have been documented in the literature: between the facial and the lingual arteries,<sup>1, 18</sup> between the inferior alveolar artery and the submental artery, and between the inferior alveolar artery through the lingual cortical plate,<sup>15</sup> and in close relationship with the lingual cortical plate in 54% of the cases.<sup>14, 22</sup>

# Recommendations for placement of implants in mandibular areas

The sites with the highest risk of clinically important bleeding are the symphysis and the canine region-these coincide with the locations of the lingual canals, a fact that might help explain this bleeding.<sup>6, 1</sup> Moreover, the concavity in the symphysis may lead to perforation of the vestibular cortical plate if the implant is placed axially in the symphysis, whereas if an implant is placed tilted in the buccolingual direction, with the implant apex toward the lingual cortical plate, it can perforate the lingual cortical plate (Figs. 9a-c). For this reason, implants should be placed slightly tilted toward the vestibular cortical plate, as shown in Figure 9c. The shape of the mandible in the posterior region is as shown in Figure 10, with a depression in the lingual cortical plate under the mylohyoid line. The depth of this submandibular fossa is greater than 2 mm (Figs. 10a & b) in 71.5-80.0% of patients.<sup>23, 24</sup>

The presence of this fossa increases the risk of perforating the lingual cortical plate and of injuring the terminal branches of the sublingual artery during implant placement. However, in the posterior mandible, this risk is lower because the sublingual artery passes further from the lingual cortical plate.<sup>25</sup> To our knowledge, only two cases of perforation of the lingual cortical plate in the posterior mandible have been reported in the literature.<sup>26</sup>

Tilting of implants in the posterior mandible is again a possible solution in order to avoid the submandibular fossa and maximize the use of the bone available in patients with bone atrophy in this region. Because the inferior alveolar nerve is closer to the mandibular lingual cortical bone<sup>27</sup> and the alveolar crest height over the submandibular fossa may be limited, a novel approach has been proposed using implants tilted in a buccolingual direction, tipping the implant apex toward the vestibule **(Fig. 10)**.<sup>28</sup>

Conventionally, longer implants have been used in the anterior mandible than in other regions of the mandible or in the maxilla, owing to the lack of important anatomical structures such as the maxillary sinus or the inferior alveolar canal. Several authors have reported the appearance of sublingual hematomas after placement of dental implants of  $\geq$  15 mm in length in the anterior region of the mandible.<sup>6, 1</sup> This is the median distance from the sublingual artery to the top of the alveolar ridge.<sup>25</sup> The use of shorter dental implants may be advisable in the anterior region to reduce the risk of severe bleeding complications.

The use of 3-D imaging techniques and planning software may be useful to reduce the risk of bleeding complications. Correa et al.

#### Figs. 9 a-c

Correct angulation of the implant **(c)** to avoid perforation of the vestibular **(a)** or lingual **(b)** cortical plate in the anterior region of the mandible. B: buccal aspect; L: lingual aspect.

#### Figs. 10 a & b

Implant tilted **(b)** to avoid perforation of the lingual cortical plate **(a)** in the posterior region of the mandible when a deep submandibular fossa is present. L: lingual aspect; B: buccal aspect. found that narrower and shorter implants tended to be selected when the available bone was studied using CBCT cross-sectional images, compared with both digital panoramic radiographs and CBCT-generated panoramic views.<sup>29</sup> Moreover, guided implant surgery may potentially enhance safety even further by avoiding vessels, nerves and other anatomical structures if the case is planned properly. However, at present, this cannot be definitively stated yet. In a recent review on guided surgery, Tahmaseb et al. found a mean deviation of up to 7.1 mm.<sup>30</sup> It is necessary to control the factors that significantly affect the accuracy of guided surgery, such as the experience of the operator,<sup>31</sup> the software used,<sup>32, 33</sup> the type of support for the guided template (soft tissue, bone or dental support), the type of surgery (flap vs. flapless) and the guided surgery system used.<sup>30</sup>

The anterior region of the mandible has a high bone density, Type I according to the Lekholm and Zarb classification.<sup>34</sup> This property helps to achieve adequate primary stability, which, together with the absence of anatomical limitations, such as the inferior alveolar nerve and reduced atrophy, has conventionally led students to place their first implants in this area. The risks of placement of dental implants in the anterior region of the mandible highlight that the conventional recommendation to students to place their first implants in the anterior region of the mandible, owing to the absence of important anatomical structures, should be reviewed.

### Conclusion

The sublingual region is densely supplied by several arteries that often anastomose. Injuring these vessels can cause serious bleeding and even threaten the patient's life through the blocking of the upper airway. In order to avoid these complications, the operator should have an extensive anatomical knowledge of this area. Moreover, tilting of implants, the avoidance of long dental implants, and careful surgical planning with the aid of 3-D imaging and planning software may also help to reduce the risks when placing implants in the anterior mandible.

### **Competing interests**

The authors declare that they have no competing interests related to this study.

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# Transcrestal sinus floor elevation performed twice with collagen sponges and using a sonic instrument

### Abstract

### Objective

The objective of this study was to describe a minimally invasive transcrestal modified technique for sinus floor elevation performed twice with a sonic instrument (Sonosurgery).

#### Materials and methods

During the first surgical stage, a split-thickness flap was dissected and an osteotomy performed to prepare a crestal bone window using a sonic surgical device. The bone window was subsequently pushed apically toward the sinus and only collagen sponges were compressed into the subantral created space. After four months of healing, a second surgical stage followed using similar procedures to those used in the first stage, and implants were subsequently placed.

#### Results

After three years, from the analyses of the cone beam computed tomography scans, no marginal loss was found and bone was observed all around the implant surface. No complaints were reported by the patient. At the clinical follow-ups, no clinical signs of periimplant softtissue inflammation and no technical complications were noted during the three-year period of observation.

#### Conclusion

The technique illustrated in the present article allowed the placement of implants of proper length in a widely pneumatized sinus where the bone height of the floor was insufficient for immediate stabilization. After three years of function, neither marginal bone loss nor clinical signs of inflammation were observed.

#### Keywords

Sonosurgery, sonic instrument, sinus floor elevation, transcrestal approach, collagen sponge, sinus lift.

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### Introduction

After tooth extraction, shrinkage of the alveolar process is expected that may reach 50% of the original horizontal width.<sup>1</sup> In the posterior maxilla, the resorption of the radicular portion of the sockets that may protrude into the sinus could yield a further bone volume reduction due to sinus pneumatization. In the molar area, the resorption is greater than in the premolar area, owing to the larger volume of the extraction sockets that requires more time to be filled by newly formed bone, thus allowing the time for sinus pneumatization.<sup>2</sup>

In periodontally compromised patients, a large sinus pneumatization, together with the concomitant alveolar crestal resorption, may result in an inadequate bone height, which may hinder the primary stability of implants in the edentulous posterior maxilla.<sup>3–5</sup>

The maxillary sinus floor elevation technique with a lateral approach has been well described in literature.<sup>6</sup> This surgical approach was based on a previously unpublished technique presented by Tatum at the Alabama Birmingham meeting in 1976. The safety and reliability of the technique have received large consensus by clinicians and researchers. Several modifications of the sinus floor elevation technique have been subsequently proposed for the surgical procedures and grafting materials used. Many of the sinus floor elevation techniques include the use of grafting materials to fill the subantral space, aiming to maintain the volume created.

However, clinical studies on sinus floor elevation performed concomitantly with implant placement have shown that the establishment of an isolated space between the bone wall surface and the sinus mucosa, resulted in spontaneous formation of new bone, even without the use of grafting materials.<sup>4-7</sup> Moreover, the integrity of the sinus membrane is known to be a prerequisite for success of the technique because it prevents the shift of the grafted material inside the sinus cavity; shifting of the material may favor acute or chronic infective complications and possibly compromise bone regeneration.<sup>8</sup> Another technique frequently adopted for sinus floor elevation requires a crestal access,<sup>9</sup> first carried out with the use of osteotomes and autologous bone as filler material.<sup>10</sup> The crestal approach may reduce the perforation of the sinus membrane (4.7%)<sup>11</sup> compared with the lateral approach (44%).12

Several modifications of the crestal approach have been subsequently proposed, aiming to elevate the sinus floor while maintaining the integrity of the Schneiderian membrane. For this purpose, a variety of osteotomes, used with or without bone fillers,<sup>13, 14</sup> or drills designed to avoid membrane perforation,<sup>15</sup> or the use of specific devices<sup>16, 17</sup> or ultrasonic instruments<sup>18, 19</sup> have been proposed. With the use of osteotomes, an elevation of the sinus membrane of up to 10 mm in total may be obtained without causing tearing.<sup>20</sup> Another modification of the transcrestal approach was proposed<sup>21-23</sup> based on the principle of the edentulous ridge expansion technique.<sup>24</sup> This approach includes the use of a blade to perform the osteotomies and, subsequently, the use of blunt osteotomes.

The preservation of sinus walls appears to have an important role in bone formation in the sinus floor elevation procedure. In fact, in an experiment in monkeys on the early healing at elevated floor sinuses,<sup>25, 26</sup> it was shown that new bone only originated from the bone walls and septa of the sinus. In that study, no evidence of bone formation was observed from the sinus mucosa, even though other studies have demonstrated that the Schneiderian membrane has the potential to produce bone.<sup>27-30</sup> A minimum height of 4-6 mm of the sinus floor has been suggested to guarantee the stability of the implant and, consequently, the success of the crestal access for sinus elevation.<sup>10, 31-35</sup> When the primary stability of an implant cannot be guaranteed, a two-stage approach may be followed and implant placement would have to be postponed for several months, depending on the quality of the filler material used.<sup>31-35</sup> A twostage procedure has also been described for sinus floor elevation through a crestal access using blades, osteotomes and a mallet.<sup>21</sup> The aim of the present study is to describe a minimally invasive two-stage technique for sinus floor elevation through a crestal access, using in both stages a trapdoor prepared with the Sonosurgery system.

### Materials & methods

The case of a patient who required oral rehabilitation by means of implants in the posterior maxillary area and presented with a widely pneumatized sinus was chosen to present the step-bystep procedure of the technique. The height of



### Transcrestal sinus floor elevation with a sonic instrument



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the sinus floor ranged between 2 mm and 4 mm, depending on the outline of the base of the sinus. It was not possible to guarantee implant primary stability; thus, a two-stage approach was followed **(Figs. 1a-c)**. Micro-cone beam computed tomography (CBCT) scans (Kodak 9000, Carestream Health, Rochester, N.Y., U.S.) were taken before surgery.

#### First stage of sinus floor elevation

A split-thickness flap was dissected using a scalpel blade (BD Beaver 376400, BD Medical Ophthalmic Systems, Waltham, Mass., U.S.). A longitudinal incision was performed on the alveolar crest 3–4 mm palatal to the center of the crest. Short paramarginal releasing incisions were performed mesially (Fig. 2a). The dissection of the flap at the buccal aspect was extended up to the mucogingival junction, leaving only a thin layer of connective tissue on the bone surface in order to better visualize the bony crest morphology. After flap elevation, a bone trapdoor was prepared with the use of a vibrating sonic handpiece (Sonosurgery, TeKne Dental, Calenzano, Italy) into which a straight micro-saw (SFS 102, Komet Dental Gebr. Brasseler, Lemgo, Germany) had been inserted. The trapdoor was produced in the center of the alveolar crest and was < 2.5 mm wide in the buccolingual plane. The bone incision was extended in a mesiodistal direction for the entire edentulous area to be treated. However, a safe distance of about 1.5 mm from the premolar was maintained to avoid damaging the root (Figs. 2b-f).

The osteotomy of the bone trapdoor was performed with a micro-saw 0.25 mm thick and exercising minimal pressure, similar to that of a pencil when writing (a maximum of 2-3 N). These incisions on the bone were performed with an external bevel, so that the bone trapdoor had a trapezoidal cross-section, the largest base being at the cranial and the smallest at the caudal aspect of the trapdoor. A continuous movement along the incisions had to be carried out by the operator using the sonic insert, gradually penetrating into the bone, until a distinct change of material texture was perceived, indicating that the base of the sinus had been reached. After that, the trapdoor was released along the osteotomies using a surgical mallet on blunt chisels (KLS Martin Group, Umkirch, Germany) with gentle taps (Fig. 3a). Collagen sponges (Gingistat, GABA VEBAS,

Rome, Italy) were placed into the space obtained in order to prevent the Schneiderian membrane from tearing, and these were subsequently pushed within the subantral space using the blunt chisels and mallet (Figs. 3b & c). The 3-D hydraulic pressure produced by the collagen soaked with blood encouraged the sinus membrane detachment from the bone walls. After sinus elevation, the buccal flap was repositioned and sutured to the palatal aspect, allowing a primary intention wound closure. A CBCT scan with a low radiation dose was taken immediately after the surgery (Figs. 4a-c). Intra-oral radiographs were taken one, two and three months after the first sinus elevation (Figs. 5a-c).

#### Second stage of sinus floor elevation

Four months after the first surgical session, an intra-oral radiograph was taken and assessed **(Fig. 5d)**. The radiographs showed that the base of the sinus had gained about 3–4 mm in height compared with the original situation, yielding a total height of about 5–6 mm, which could allow for primary implant stability. No clinical signs of inflammation were observed. A surgical procedure similar to that used in the first stage was performed, including the mucosal incision. Again, a buccolingual crestal osteotomy < 2.5 mm wide was made **(Figs. 6a & b)**.

The augmented dimensions of the sinus floor compared with the initial situation allowed the execution of deeper osteotomies with more pronounced bevels than those carried out during the previous surgical stage. Consequently, the bone trapdoor was higher and wider in the cranial regions in comparison with that prepared in the first surgical stage.

Chisels of increasing thickness were used to distract the bone toward the sinus, following the incisions made with the sonic micro-saw. This, in turn, meant that the chisels had a working direction with the same angulation as the osteotomies. Once the trapdoor had been split and mobilized by blunt chisels and a mallet, both buccally and palatally from the parent bone, collagen sponges were added and an implant with a conical shape (Pilot, Sweden & Martina, Due Carrare, Italy) was placed (Fig. 6c). The implant apex pushed the collagen and the bone further, producing an additional sinus floor elevation. Implant primary stability was obtained by means of the pressure of the

#### Figs. 1a-c

First sinus floor elevation stage in the three planes. In the initial CBCT scan, a fracture of the second molar and a periapical radiolucency were observed. The insufficient sinus floor height in the first molar position did not allow for immediate implant placement. (a) Panoramic view. (b) Cross-sectional view. (c) Axial view.

#### Figs. 2a–f

Clinical view of the surgical procedures. (a) Site after flap dissection and extraction of the first molar. The osteotomies were performed with an external bevel using a micro-saw 0.25 mm thick and exercising minimal pressure. The bevel cuts were orientated (b) mesially, (c) palatally, (d) distally, and (e) buccally, respectively. (f) The osteotomies of the trapdoor were finalized.

#### Figs. 3a–c

(a) The elevation of the trapdoor and of the sinus floor was performed with a surgical mallet on blunt chisels.
(b) Collagen sponges were placed into the space obtained, and these were subsequently pushed within the subantral space using the blunt chisels and mallet.
(c) Situation after the placement of collagen sponges.

#### Figs. 4a-c

A CBCT scan was taken immediately after the surgery. (a) Panoramic view. (b) Cross-sectional view. (c) Axial view.

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#### Figs. 5a–d

Radiographs showing the healing (a) one, (b) two, (c) three and (d) four months after the first sinus floor elevation procedure.

#### Figs. 6a–d

Clinical view of the surgical procedures of the second sinus floor elevation. (a) Buccal flap elevated. (b) The trapdoor was prepared, split and mobilized from the parent bone by chisels and a mallet. (c) Collagen sponges were added and an implant with a conical shape was placed. (d) The flaps were sutured with apical repositioning at the buccal aspect.

#### Figs. 7a–c

Low-dose CBCT scan taken immediately after the second surgery. (a) Panoramic view. (b) Cross-sectional view. (c) Axial view.





Figs. 5a–d



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Journal of Oral Science & Rehabilitation implant collar on the walls of the access. The buccal and lingual flaps were sutured with apical repositioning at the buccal aspect **(Fig. 6d)**. A low-dose CBCT scan was taken immediately after the second surgery **(Figs. 7a–c)**.

Prosthesis delivery and follow-up

After four months of uneventful healing, impressions were taken and a metal-ceramic crown was fabricated and seated over the implant **(Figs. 8a–c)**. Checkups were performed during the healing period and regularly up to three years afterward. Intra-oral radiographs were taken immediately after prosthesis seating and yearly thereafter. strong pulling on the flaps during surgery. Moreover, it allows for easier access to the distal zones with less exposure of the surgical area. The absence of biomaterial grafts, other than the rapidly resorbable collagen sponge, decreases the possible loss of material into the sinus and, consequently, the risk of infection in case of unexpected perforation of the sinus mu-

### Results

After three years, from the analyses of the CBCT scans, no marginal loss was found and bone was observed all around the implant surface. The location of the implant apex corresponded to the new sinus floor (Figs.9a–c). No complaints were reported by the patient. At the clinical follow-ups, no clinical signs of periimplant soft-tissue inflammation and no technical complications were noted during the three-year period of observation (Fig.9d).

### Discussion

The surgical technique with a crestal trapdoor approach may present advantages over classical sinus floor elevation performed through a lateral window access. The crestal approach, conversely to the lateral access, avoids opening large flaps, performing long vertical releasing incisions, and strong pulling on the flaps during surgery. Moreover, it allows for easier access to the distal zones with less exposure of the surgical area.

The absence of biomaterial grafts, other than the rapidly resorbable collagen sponge, decreases the possible loss of material into the sinus and, consequently, the risk of infection in case of unexpected perforation of the sinus mucosa. Moreover, no membranes are needed to cover the access osteotomy, reducing the total biomaterial cost.<sup>36</sup> The absence of grafted material allows a more reliable radiographic evaluation of the progressive mineralization within the elevated area, whereas when a radiopaque grafting material is used, its radiopaque nature may hinder the evaluation of bone formation.

The use of a crestal access may avoid crossing the anastomosis between the posterior superior alveolar artery and the infraorbital arteries. This anastomosis may be quite large in diameter and may cause severe hemorrhages when it is unintentionally damaged and possibly

#### Figs. 8a-c

Clinical view of the outcome. (a) Implant four months after the second sinus floor elevation. (b & c) Crown just seated over the implant from the occlusal and buccal views, respectively.

#### Figs. 9a-d

Low-dose CBCT scan taken after three years. (a) Panoramic view. (b) Cross-sectional view. (c) Axial view. (d) Clinical view.



compromise the blood supply of the region.<sup>37-40</sup> One of the most important advantages of the present technique is, however, the presence of intact bone walls, whereas in the lateral access technique, the lateral wall is removed to a large extent, compromising bone formation. In fact, it has been shown that bone is formed from parent bone, while the sinus mucosa does not contribute to such formation, at least during the earliest periods of healing.<sup>25, 26</sup> Finally, in the case of thin alveolar ridges, a split-crest procedure may be applied concomitantly, so that the width of the ridge may also be augmented.

The crestal approach described in the present article also has some disadvantages, such as the low visibility within the elevated zone and the complex learning curve. The chisels and mallet have to be used carefully to avoid damage to the sinus membrane and discomfort for the patient. Moreover, the technique illustrated in the present article requires the sinus elevation to be performed twice, the implant being placed during the second surgery.

The sonic handpiece instrument and the micro-saw inserts used allow the operator to perform sharp and thin incisions with a clear view of the area, cleaned of bone smear and blood by irrigation. Moreover, incision with vibrating tools weakens the bone along the lines of the osteotomy, minimizing the use of the mallet and consequently resulting in less discomfort for the patient. Sonic instruments have been shown to produce a very low increase in temperature compared with ultrasonic instruments<sup>41</sup> and very limited soft-tissue damage.<sup>42–44</sup> The use of sonic instruments has been proposed for the extraction of impacted canines<sup>45</sup> and successfully tested for implant placement in an animal experiment.<sup>46</sup>

### Conclusion

The technique illustrated in the present article allowed the placement of implants of proper length in a widely pneumatized sinus where the bone height of the floor was insufficient for immediate stabilization. After three years of function, neither marginal bone loss nor clinical signs of inflammation were observed.

### **Competing interests**

IA developed the Sonosurgery device and microsaw inserts used in the treatment of this case, and hence declares a competing interest. DB declares that he has no competing interests in relation to this study. The study was self-funded by the authors.

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# **Primary stability** of dental implants with different thread geometries placed by clinicians with different clinical experience: An*in vitro* study

#### Abstract

#### Objective

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The objective of this study was to establish the primary stability of implants with two different designs placed into artificial bone (Type II and Type IV density) by clinicians with different levels of experience using the same implant bed preparation protocol.

### Materials and methods

An *in vitro* experiment was performed using polyurethane resin bone blocks resembling Type IV and Type II bone density. Eighty control implants (Replace Select Tapered with symmetric threads, Nobel Biocare) and 80 test implants (NobelActive, tapered with progressive threads, Nobel Biocare) were placed. The implant diameter was 4.3 mm and the length was 11.5 mm for both groups. Implant beds were prepared by two clinicians with different levels of experience (expert and intermediate), and subsequently implants were placed with the platforms at crestal level. The stability parameters of insertion torque and implant stability quotient were recorded when the implants reached the insertion depth. A two-way ANO-VA was used to evaluate differences within the groups; multiple comparisons were performed using the Tukey test. Significance was set at *p* < 0.05.

### Results

Stability parameters were significantly higher for Type II bone for both clinicians compared with Type IV bone (p < 0.05). Implants with a progressive thread design showed a tendency to increased stability compared with implants with a symmetric thread design in Type IV bone (p < 0.05). The clinicians' level of experience did not affect the implant stability (p > 0.05).

### Conclusion

Within the limitations of this *in vitro* study, the following conclusions were drawn:

- The clinician's level of experience does not affect the implant stability in Type IV and Type II bone when the same implant bed preparation protocol is used.
- The stability of tapered implants with symmetric threads and those with progressive threads is increased in Type II bone density.
- The implant stability in soft bone is similar for tapered implants with a symmetric thread design and for those with a progressive thread design.

#### Keywords

Implant design, implant stability, soft bone, hard bone, level of experience.

#### Factors affecting primary stability of tapered implants with different thread design

### Introduction

Dental implant stability is important for achieving osseointegration. The implant body design and the thread geometry are significant for improvement of the mechanical implant stability. Tapered implants appear to have better mechanical stability than do parallel-walled implants.<sup>1</sup> A study comparing the insertion torque of tapered and of cylindrical implants has shown that tapered implants are associated with higher primary stability than are cylindrical implants.<sup>2</sup> In an experimental study on dogs, Kim et al. compared the mechanical properties of tapered and parallel-walled implants in terms of success rates.<sup>3</sup> Maximum insertion torque and maximum removal torque were assessed. The results showed significantly higher values of maximum insertion torque and maximum removal torque for tapered implants than for parallel-walled implants. In addition, use of cylindrical nonthreaded implants has been associated with a higher implant failure rate compared with threaded implants.<sup>4</sup> Moreover, it has been postulated that tapered implants have a better load distribution to surrounding bone by mimicking the natural root form.<sup>5</sup>

The implant body design and the thread geometry have been compared in a multicenter clinical study with immediate loading protocols. Different implant designs, such as tapered implants with a symmetric thread design (Nobel-Replace Tapered Groovy), tapered implants with a progressive thread design (NobelActive internal connection), and cylindrical implants with the same thread profile as the NobelActive internal connection but with a narrow neck (NobelActive external connection), presented a similar cumulative survival rate after three years of loading.<sup>6</sup> In addition, the bone condensation technique in cancellous bone and other surgical techniques may influence implant stability.<sup>7</sup>

The quality of the osteotomy might be influenced by the clinician's surgical experience<sup>1, 8</sup> and therefore the primary stability could be



affected. There is a lack of studies in the literature evaluating primary stability and its relation to surgical experience. Therefore, the aim of this study was to evaluate the primary stability of two implant designs with different thread geometries placed by two clinicians with different levels of clinical experience in implant surgical procedures and placed into two different bone qualities.

### Materials & methods

Two surgeons with different levels of experience performed the drilling: expert (GR, 25 years' experience in implant dentistry, had placed more than 10,000 implants) and intermediate (RD, 15 years' experience in implant dentistry, had placed fewer than 5,000 implants). The implant bed on synthetic bone blocks was prepared for two different implant designs: Replace Select Tapered regular platform (Nobel Biocare, Gothenburg, Sweden), a tapered implant with a symmetric thread design (TST) and conical connection; and

## Figs. 1a & b Synthetic bone blocks used

in the experiment. (a) Type II dense bone. (b) Type IV soft bone.

#### Table 1

Mechanical properties of the synthetic blocks used in the experiment.

Table 1	Mechanical properties	Block of Type II density	Block of Type IV density	
	Compressive yield strength	31.0 MPa	2.30 MPa	
	Compressive modulus	0.759 GPa	0.032 GPa	

Implants	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Tab
placed	n = 40	n = 40	n = 40	n = 40	n = 40	n = 40	n = 40	n = 40	
N = 320	а	b	с	d	е	f	g	h	
ISQ value ( <b>mean ± S.D.</b> )	63 ± 4 <sup>e, f, g, h</sup>	63 ± 3 <sup>e, f, g, h</sup>	65 ± 3 <sup>e, f, g, h</sup>	65 ± 5 <sup>e, f, g, h</sup>	54±3	59 ± 2 <sup>e, g</sup>	53 ± 2	58 ± 1 <sup>e, g</sup>	

Implants	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Tab
placed	n = 40	n = 40	n = 40	n = 40	n = 40	n = 40	n = 40	n = 40	
N = 320	а	b	с	d	е	f	g	h	
IT value (mean ± S.D. in N cm)	40 ± 2 <sup>e, f, g, h</sup>	42 ± 4 <sup>e, f, g, h</sup>	41±5 <sup>e, f, g, h</sup>	43 ± 2 <sup>e, f, g, h</sup>	18 ± 2	20 ± 1	17 ± 2	19 ± 1	

#### Table 2

Differences in primary stability were observed between different bone densities and between different implant designs in terms of ISQ. The Tukey multiple comparison test showed differences favoring higher stability in Type II bone density compared with Type IV. Regarding implant design, implants with a progressive thread design in Type IV bone density favored higher stability. There were no differences in implant stability regarding level of experience.

#### Table 3

Differences in primary stability were observed between different bone densities in terms of IT. The Tukey multiple comparison test showed differences favoring higher stability in Type II bone density compared with Type IV. Regarding implant design and level of experience, there were no differences in implant stability. NobelActive regular platform (Nobel Biocare), a tapered implant with a progressive thread design (TPT) and conical connection. The implant diameter of 4.3 mm and length of 11.5 mm were used for all groups.

For this experimental controlled study, two synthetic bone blocks (Sawbones, Pacific Research Laboratories, Vashon Island, Wash., U.S.) measuring 13 cm × 18 cm × 4 cm, with two different densities (Type II and Type IV), were used (**Figs. 1a & b**). The Type II solid block was of 0.85  $\pm$  0.4 g/cm3 in density and the Type IV cellular block was of 0.45  $\pm$  0.10 g/cm<sup>3</sup> in density. The mechanical properties of the artificial blocks used in the study are presented in **Table 1**.

Eight experimental groups were created as follows: **Group 1:** Expert + Type II blocks + TST **Group 2:** Expert + Type II blocks + TPT **Group 3:** Intermediate + Type II blocks + TST **Group 4:** Intermediate + Type II blocks + TPT **Group 5:** Expert + Type IV blocks + TST **Group 6:** Expert + Type IV blocks + TPT **Group 7:** Intermediate + Type IV blocks + TST **Group 8:** Intermediate + Type IV blocks + TPT.

A total of 320 perforations were performed, 160 perforations on each block. The allocation of samples to groups was performed according to randomization software (Research Randomizer),<sup>9</sup> and after the allocation each one of the eight groups was composed of 40 samples (**Fig. 2**).

#### Drilling procedures

The blocks were fixed to a metallic platform to reduce movement during drilling, as well as to ensure the same experimental conditions for both operators. The drilling protocol used was recommended by the manufacturer and was performed by a calibrated operator. Instructions were provided to both clinicians regarding the manner in which they were to prepare the implant bed. During drilling, an in-and-out motion and drilling in the bone for 1-2 s without stopping the handpiece motor were performed until the drill reached the depth reference line (11.5 mm). The drilling parameters were the same for both operators: drilling speed of 800 rpm with no irrigation, and the drills were replaced after ten uses as recommended by the manufacturer.

- Drilling for the Replace Select Tapered implant in Type II and Type IV bone: The drilling started with the 2.0 mm diameter pilot drill, followed by the 3.5 mm diameter tapered drill and finished with the 4.3 mm tapered drill.
- Drilling for the NobelActive implant in Type IV bone (soft-bone protocol): The drilling started with the 2.0 mm diameter drill, followed by a stepped drill with 2.4/2.8 mm diameter steps and finished with a stepped drill with 2.8/3.2 mm diameter steps.
- Drilling for the NobelActive implant in Type II bone (hard-bone protocol): The drilling started

#### Factors affecting primary stability of tapered implants with different thread design



with the 2.0 mm diameter drill, followed by The implants were then retrieved and placed into a stepped drill with 2.4/2.8 mm diameter steps and finished with a stepped drill with 3.2/3.6 mm diameter steps.

## the hard bone for the evaluation of primary stability. A total of 320 evaluations were performed.

#### Primary stability evaluation

### The evaluation of primary stability was performed according to the insertion torque (IT) and the implant stability quotient (ISQ) as follows:

- IT was measured during implant insertion by the implant motor (DENTSPLY, Waltham, Mass., U.S.) and was recorded in N cm. The peak values were reached when the implant platform was located at the surface of the bone block (11.5 mm). Each placed implant resulted in a single value, and mean values were collated by group and compared.
- ISQ was recorded using resonance frequency analysis with the Osstell Mentor device (Osstell, Göteborg, Sweden). Specific transducers were used, and replaced after ten uses until all of the measurements had been performed. Measurements were taken as follows: The transducer was screwed to the placed implant. The probe was laterally oriented in relation to the transducer and measurements were taken. Each measurement was repeated in triplicate and mean values were recorded. All measurements were performed by an independent,

### Fig. 2

Study design scheme for the 320 implant beds prepared in synthetic bone blocks with different bone densities.

- Replace Select Tapered: This implant possesses a conical profile with the same thread profile. The body is tapered, the neck has micro-threads and the connection is conical (Fig. 3b).

Implant characteristics

- NobelActive: This implant possesses a variable-thread profile, wider (vertically) and shorter (horizontally) as it progresses from the neck area, in which there are micro-threads. In the apical region, the implant has a pronounced tapered body with sharp threads to facilitate insertion and cutting of unprepared bone. The connection is conical and the coronal region is back-tapered coronally, which results in a reduction of the platform diameter (Fig. 3a).

### Implant placement

A total of 160 implants were placed in a random scheme in 320 implant bed preparations, until they reached the crestal level, leaving the implant platforms flush with the block surface (Fig. 4). The implants were placed first into the soft bone and primary stability was evaluated afterwards.

#### Figs. 3a & b

Implant designs used for the implant stability evaluation. (a) Tapered implant with a symmetric thread design. (b) Tapered implant with a progressive thread design.



unbiased examiner. Data were expressed as ISQ values (1–100). Mean values were collated by group and compared.

### Statistical analysis

The statistical analyses were performed with SPSS software (Version 13.0; SPSS, Chicago, Ill., U.S.). For the evaluation of the normality distributions of each group, the Shapiro-Wilk test was used. A two-way ANOVA was used to evaluate differences within groups and the impact of the operator on the stability parameters. Multiple comparisons were performed using the Tukey test. Significance was set at *p* < 0.05. Data were expressed as mean value  $\pm$  S.D. and ranges were (p > 0.05; **Tables 2 & 3**). calculated for each group.

### Results

All of the implants were mechanically stable, but implant stability differed between groups. Regarding bone density, the results showed higher stability (p < 0.05) evaluated by ISQ in dense bone (Groups 1, 2, 3 and 4) compared with soft bone (Groups 5, 6, 7 and 8). Regarding the effects of the implant design, the results showed that

the tapered implants with a progressive thread design had increased primary stability in soft bone compared with the tapered implants with a symmetric thread design for different evaluation groups (Groups 5, 6, 7 and 8; p < 0.05). However, within the dense bone groups, no significant differences in terms of stability were found for the two implant thread designs (Groups 1, 2, 3 and 4; p > 0.05). The evaluation by IT values did not show differences in stability in soft bone (p > 0.05; Tables 2 & 3).

Regarding the effects of the operator's level of experience on the implant stability, no statistically significant differences were observed between the implant groups in IT or ISQ values

### Discussion

Some authors consider that the implant survival rate is higher for experienced clinicians,<sup>10-13</sup> while others have found similar cumulative implant survival rates independent of the clinicians' level of experience.14, 15

However, there is a lack of research in the literature regarding the effect of level of experience on primary stability; therefore, the present Fig. 4



#### Fig. 4

Implant insertion level for the evaluation of the IT and the ISQ values. The implants were placed with the most coronal portion of the platform flush with the block surface.

*in vitro* study compared the primary stability of implant designs with symmetric or progressive threads in soft and hard bone placed by clinicians with different levels of surgical experience.

There is great variability in the definition of level of experience used in previous studies. Lambert et al. regarded an experienced clinician as one who had placed more than 50 implants and an inexperienced one as having placed fewer than 50 implants.<sup>13</sup> Preiskel and Tsolka considered experienced clinicians those periodontists and oral and maxillofacial surgeons with more than two years of experience with dental implants and they considered as inexperienced those oral and maxillofacial surgeons just beginning their involvement in dental implants.<sup>16</sup> Hinckfuss et al. classified level of experience as novice (dental students with no clinical surgical implant experience who had completed an instructional laboratory course in placing implants in typodonts), intermediate (graduate periodontology residents who had placed between 20 and 80 implants clinically) and experienced

(periodontists who had placed over 300 implants clinically).<sup>17</sup>

The present experimental study assigned to the surgeons two levels of experience: expert (25 years' experience in implant dentistry and more than 10,000 implants placed) and intermediate (15 years' experience in implant dentistry and fewer than 5,000 implants placed). Compared with other studies, this is one of the strictest measurements of clinician experience. The rationale is based on a study in psychology that demonstrated that level of experience is determined, among others, by learning (skills acquired through repetition) and performance (quality of the procedures that is dependent on the performer);<sup>18</sup> therefore, it can be asserted that the number of years of experience and the number of procedures performed used in the present experiment are reasonable.

The results of the present work showed that the effects of the thread design were beneficial for primary stability, especially in the soft bone, as measured by ISQ value and that there was no significance in the final implant stability regarding the two clinicians' levels of experience for both bone qualities (soft and hard bone) and the two implant designs.

The IT values were not conclusive for differences between implant design and primary stability. Apparently, the sensitivity of the ISQ meter is able to detect very small differences,<sup>19</sup> while IT underestimates the stability values. The motor used for the evaluation of IT in this experimental study operates in increments of 5 N cm; therefore, values below 5 N cm can be underestimated.

However, the implants used had a tapered shape and this may be the main reason that the stability of the implants was similar (p > 0.05). Previous studies have shown that implants with symmetric threads and a cylindrical or tapered implant body shape have different primary stability when they are placed in soft bone (parallel-walled implants have lower stability) and the clinician's level of experience appears to be important.<sup>1.8</sup> The data in this study confirm that the tapered implant design used (Replace Select Tapered and NobelActive) may achieve excellent stability for clinicians with different levels of experience in an experimental set.

A recent study comparing the survival rates of dental implants placed in a residency program under direct supervision for the treatment of patients with overdentures has shown a high survival rate of 97.7% within a period of two years.<sup>20</sup> The researchers concluded that novice general dentistry residents can successfully place mandibular implants and restore them with overdentures under direct supervision, resulting in subsequent enhancement of the patients' satisfaction with their mandibular dentures.

However, new clinical trials by a national group of dental practitioners presented higher failure rates for implants placed by general dentists compared with those for implants placed by clinicians with specialty training.<sup>21</sup> For other studies, experience was defined as number of implants placed, and clinical studies showed that those clinicians (n = 1,260) with experience of placing fewer than 50 implants presented a higher failure rate of 3.5%, compared with surgeons (n = 1,381) with greater surgical experience (50 or more implants), who showed a failure rate of 1.8%.<sup>13</sup>

There is no doubt that primary stability of dental implants is of significant importance for achieving long-term success, especially when implants are loaded immediately after placement.<sup>22</sup> The mechanical stability of the implant is very important, particularly in soft bone, and the thread design may provide better mechanical anchorage in the surrounding bone. A previous study evaluating implant stability based on the thread pitch width showed that implants with a narrow thread pitch had a higher stability owing to the greater surface area, compared with implants with a wider thread pitch when they were placed in cancellous bone.<sup>23</sup>

### Conclusion

Within the limitations of this *in vitro* study, the following conclusions can be drawn:

- The operator's level of experience, expert versus intermediate, does not affect the implant stability in Type IV and Type II bone when the same implant bed preparation protocol is used.
- The stability of tapered implants with symmetric threads and those with progressive threads is increased in Type II bone density.
- The implant stability in soft bone is similar for tapered implants with a symmetric thread design and for those with a progressive thread design.

#### **Competing interests**

The authors declare that they have no competing interests related to this study. No financial support was received for this study.

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# The coronally advanced flap in the treatment of bilateral multiple gingival recessions with or without tunneling the maxillary midline papilla: A randomized clinical trial

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### Abstract

#### Objective

The objective of this study was compare the clinical results of the coronally advanced flap (CAF) without vertical releasing incisions using (*i*) a tunneling procedure on the maxillary midline papilla (test) or (*ii*) a conventional technique (control) in which the midline papilla is incised and elevated like any other papilla in the procedure.

Materials and methods

Twenty healthy subjects with at least two Miller Class I gingival recessions (RECs) crossing the midline in the maxilla were enrolled for the study. Fifty-six (mean initial REC =  $2.3 \pm 0.9$  mm) and 75 (mean initial REC =  $2.3 \pm 1.1$  mm) RECs were treated in the test and control groups, respectively. All of the cases were treated by means of CAF without vertical releasing incisions: ten were randomly assigned to the test group and ten to the control group. Clinical evaluations in terms of REC were performed at baseline (preoperative) and after one year. Differences in REC reduction (RECred) and in complete root coverage (CRC) between the two groups were statistically analyzed both for all of the RECs of each treatment group and for the central incisors only.

### Results

The mean final REC at 12 months for the test group was  $0.3 \pm 0.5$  mm and for the control group  $0.4 \pm 0.6$  mm, with a RECred of  $2.1 \pm 0.9$  mm (89.1% of the initial REC) and of  $1.9 \pm 0.9$  mm (84.3% of the initial REC), respectively. Forty-three out of 56 (76.8%) RECs in the test group and 53 out of 75 (70.7%) in the control group achieved CRC.

The initial mean REC at the central incisors was  $2.3 \pm 0.9$  mm and  $2.7 \pm 1.2$  mm, respectively, for the test and control groups. The mean final REC after 12 months was  $0.3 \pm 0.6$  mm and  $0.4 \pm 0.6$  mm, respectively, for the test and control groups with a RECred from the baseline of  $2.0 \pm 0.9$  mm (87%) for the test group and of  $2.3 \pm 1.0$  mm (87%) for the control group. Fifteen out of 20 (75%) RECs in the test group and 14 out of 20 (70%) in the control group achieved CRC.

### Conclusion

There was no statistically significant difference between the two groups for RECred and CRC for either all of the RECs or those at the central incisors only. CAF performed with tunneling of the midline papilla is a safe procedure that shows similar results to conventional CAF surgery.

#### K e y w o r d s

Coronally advanced flap, gingival recession, papilla tunneling, mucogingival surgery, dental esthetics.



#### Introduction

The coronally advanced flap (CAF) is a surgical procedure for treating gingival recessions (RECs)<sup>1</sup> by advancing the residual keratinized tissue surrounding an exposed root to cover the cementoenamel junction. It can be used alone or in combination with a connective tissue graft,<sup>2</sup> an enamel matrix derivative<sup>3</sup> or various connective tissue graft substitutes,<sup>4,5</sup> especially when keratinized tissue limiting the REC is not adequate to allow stable results.

It can be performed on multiple adjacent root exposures and can be considered the technique of choice for such a clinical purpose,<sup>6</sup> with specific advantages when treating gingival RECs in esthetic areas. On multiple adjacent RECs, CAF can even be performed without vertical releasing incisions<sup>7</sup> with increased possibility of achieving complete root coverage (CRC), better esthetic results owing to the complete absence of keloid aspects sometimes shown after healing of the vertical releasing incisions and a better postoperative course for the patient.<sup>8</sup>

A modified approach was introduced in the treatment of bilateral gingival RECs in the esthetic area using CAF.<sup>9</sup> Later, other authors<sup>10, 11</sup> described a minimally invasive technique for the management of the papilla situated between the central incisors using the tunneling approach to advance a flap for covering either a subepithelial connective tissue graft or a substitute graft in association with a specific flap design.<sup>12</sup> A tunnel can be surgically created underneath the buccal aspect of the midline papilla, allowing the mobilization of the gingival margin on both the adjacent central incisors and maintaining postoperative ideal soft-tissue stability.

The aim of the present study is to compare the results obtained at one-year clinical follow-up in the treatment of multiple Miller Class I gingival RECs of the maxillary esthetic area, using CAF with the papilla tunneling technique or with the conventional technique. Furthermore, the aim is to compare the specific results obtained at the buccal aspect of the maxillary central incisors with CAF and the maxillary midline papilla tunneling technique and with the conventional CAF technique.

#### Materials & methods

Twenty subjects with multiple maxillary bilateral gingival RECs in the area between the left second premolar and the right second premolar (at least two adjacent teeth with Miller Class I REC with at least 2 mm of residual keratinized tissue and at least one such tooth on each side of the maxilla), 11 females and 9 males (age range of 22–60) in good general health were selected. After the first examination, all of the patients underwent a single session of prophylaxis with instructions on proper oral hygiene techniques, scaling and professional tooth cleaning by means of rubber cups and prophylaxis paste.

Further examinations were scheduled once each patient was able to demonstrate adequate supragingival plaque control with an effective and atraumatic brushing technique. At baseline, immediately prior to surgery, for each tooth involved in the treatment, REC was measured from the cementoenamel junction to the gingival margin and residual keratinized tissue apical to each REC was measured from the gingival margin to the mucogingival junction. Probing pocket depth was measured on the mesial and distal aspects of each tooth involved in order to identify Miller Class III RECs that would not be evaluated. RECs with residual keratinized tissue of less than 2 mm at baseline were treated during surgery but excluded from the evaluation. A sequence of randomization was generated by a subject not involved in the research, instructed to randomly place ten sheets of paper bearing "tunneling" and ten "no tunneling" inside 20 progressively numbered envelopes.

The surgical protocol was the following: After local anesthesia (articaine with 1:100,000 epinephrine), exposed roots were gently instrumented by means of Gracey curettes and rotating diamond burs mounted on a micromotor handpiece. The envelope was then opened in order to determine whether the surgical design of the flap was to be performed according to a tunneling procedure on the midline papilla or whether conventional CAF was to be performed. In the case of conventional CAF, the flap was designed with marginal and papillary incisions performed with a #15C blade, according to the CAF technique for monolateral multiple RECs7 without vertical releasing incisions, ideally dividing the right and the left sequence of RECs located at each side of the midline as an independent monolateral root coverage procedure with its centre of rotation on

#### Coronally advanced flap in the treatment of bilateral multiple gingival recessions







Figs. 3 & 4

#### Fig. 1

Test case: Preoperative situation.

#### Fig. 2

Test case: Postoperative situation after CAF performed with a tunneling procedure on the midline papilla.

#### Fig. 3

Test case: Clinical situation at seven days, immediately after suture removal.

#### Fig. 4

Test case: Clinical situation at two months.

#### Fig. 5

Test case: Clinical situation at one year.



the homolateral canine.<sup>12</sup> In tunneling cases, the midline papilla was tunneled with a dedicated instrument (stoma periosteal elevator for tunneling, 2 mm, Storz am Mark, Emmingen-Liptingen, Germany), while in conventional CAF cases, two incisions were carried out on the midline papilla, outlining the surgical papilla that was subsequently elevated. Thereafter, the flap was raised with a sequence of split-thickness dissection of the papillae, followed by a full-thickness elevation almost 2 mm apical to the mucogingival junction and by a split-thickness dissection in the superficial layers

of the muscles underneath the alveolar mucosa until a passive coronal displacement of the flap was obtained. The residual epithelium covering the papillae in the portion coronal to the oblique incisions outlining the surgical papillae in the flap was then removed by means of a #15C blade. In every case in which during surgery a frenum was considered detrimental for the final result, a minimal frenectomy was performed.

The flap was then secured in a coronal position, covering the cementoenamel junction of each involved tooth by suturing the papillae with

#### Coronally advanced flap in the treatment of bilateral multiple gingival recessions

Table '

	Test (tunnel; <i>n</i> = 56) Mean ± S.D.	Control (no tunnel; <i>n</i> = 75) Mean ± S.D.	
Initial recession (mm)	$2.3 \pm 0.9$	2.3 ± 1.1	
Final recession (mm)	0.3 ± 0.5	$0.4 \pm 0.6$	
Recession reduction (mm)	2.1 ± 0.9	1.9 ± 0.9	

Table 2

	Complete root coverage	Incomplete root coverage	Total
Test (tunnel)	43	13	56
Control (no tunnel)	53	22	75
Total	96	35	131

Table 3		Test (tunnel; <i>n</i> = 20) Mean ± S.D.	Control (no tunnel; <i>n</i> = 20) Mean ± S.D.
	Initial recession (mm)	$2.3 \pm 0.9$	2.7 ± 1.2
	Final recession (mm)	0.3 ± 0.6	0.4 ± 0.6
	Recession reduction (mm)	2.0 ± 0.9	2.3 ± 1.0

Table 4

	Complete root coverage	Incomplete root coverage	Total
Test (tunnel)	15	5	20
Control (no tunnel)	14	6	20
Total	29	11	40

synthetic monofilament 5-0 sutures (Monomyd, Butterfly Italia, Cavenago di Brianza, Italy; POLI-NYL, Sweden & Martina, Due Carrare, Italy; Cytoplast, Osteogenics Biomedical, Lubbock, Texas, U.S.). In the postoperative period, ketoprofen (OKi, Dompé, Milan, Italy) according to the patient's need was prescribed for pain control. Patients were instructed to abstain from consuming hot food and beverages for two days and from chewing hard food in the area of intervention until suture removal. Equally, no flossing or brushing around the treated teeth was allowed and a 0.12% chlorhexidine spray (CURASEPTADS Spray, Curaden, Saronno, Italy) was prescribed for local application t.i.d. after meals. After suture removal, proper oral hygiene measures were re-established, starting with brushing with an ultrasoft postoperative toothbrush. Furthermore, examinations were scheduled for 2, 4, 8 and 12 months, measuring again all preoperative clinical parameters at the 12-month control (Figs. 1–5). REC reduction (RECred) and the CRC rate for the test and control groups were calculated for all teeth involved in the treatment and for the central incisors adjacent to the midline papilla. Differences in terms of RECred and the CRC rate between the test and control groups were determined according to statistical analysis for all of the RECs by means of the Student's *t*-test for independent samples and the chi-squared test, respectively, and limited to those at the central incisors by the Mann–Whitney *U* test and Fisher exact test, respectively. A *p*-value of < 0.05 was considered statistically significant.

### Results

Fifty-seven Miller Class I RECs were treated in the test group and 76 in the control group. One REC exhibiting less than 2 mm of residual keratinized tissue in each group received a connective tissue graft or a graft substitute and was not considered in the study. Therefore, 56 (mean

#### Table 1

Recession reduction: Comparison between the test and control groups.

#### Table 2

Complete root coverage: Comparison between the test and control groups.

#### Table 3

Recession reduction of central incisors: Comparison between the test and control groups.

#### Table 4

Complete root coverage of central incisors: Comparison between the test and control groups.

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initial REC =  $2.3 \pm 0.9$  mm) and 75 (mean initial REC =  $2.3 \pm 1.1$  mm) RECs were analyzed for each treatment group.

The mean final REC at 12 months was  $0.3 \pm 0.5$  mm for the test group and  $0.4 \pm 0.6$  mm for the control, with a RECred of  $2.1 \pm 0.9$  mm (89.1% of the initial REC) and  $1.9 \pm 0.9$  mm (84.3% of the initial REC), respectively. The Student's *t*-test for unpaired data did not find a statistically significant difference in RECred between the two groups (p = 0.9692; **Table 1**). Forty-three out of 56 (76.8%) RECs in the test group and 53 out of 75 (70.7%) in the control group achieved CRC. The chi-squared test did not demonstrate a statistically significant difference in the CRC rate between the two groups (p = 0.4336; **Table 2**).

Table 3 shows the data of the RECs at the central incisors adjacent to the tunneled or not tunneled papilla. The initial mean REC at the central incisors was  $2.3 \pm 0.9$  mm and  $2.7 \pm 1.2$  mm, respectively, for the test and control groups. The mean final REC after 12 months for the test and control groups was  $0.3 \pm 0.6$  mm and  $0.4 \pm 0.6$  mm, respectively, with a RECred from the baseline of  $2.0 \pm 0.9$  mm (87%) for the test and  $2.3 \pm 1.0$  mm (87%) for the control groups. The Mann–Whitney U test did not show a statistically significant difference in RECred between the two groups (p = 0.27572; Table 3). Fifteen out of 20 (75%) RECs in the test group and 14 out of 20 (70%) in the control achieved CRC. The Fisher exact test did not find a statistically significant difference in the CRC rate between the two groups (p = 0.7401; Table 4).

#### Discussion

The results of CAF performed with a tunneling procedure underneath the maxillary midline papilla were better in terms of RECred than those of the control group, although the differences did not achieve statistical significance. They were 89.6% aligned with the outcomes of overall periodontal plastic procedures from a recent systematic review of the literature (86.27%)<sup>6</sup> and with those from another publication on CAF with no releasing incisions in the same esthetic area (89.1%).<sup>13</sup> However, limited to the same esthetic area, they were slightly inferior to those of both CAF improved with an orthodontic device for a sling suture and flap securing in a more coronal position (96.2%)<sup>13</sup> and CAF alone (95.0%),<sup>14</sup> even

on monolateral RECs  $(97.0\%)^7$  or in a limited number of patients and RECs (97.0%).<sup>9</sup> In this study, CRC too (76.8%) was comprised in the upper level of the range of outcomes of overall periodontal plastic procedures  $(23.8-89.3\%)^6$ and showed better results than CRC obtained with conventional CAF with no releasing incisions in the same esthetic area  $(61.0\%)^{13}$  but worse than the outcomes obtained both with improved CAF  $(84.6\%)^{13}$  and CAF alone (84.0%; 88.0%; $89.0\%)^{14, 7, 9}$  even within the above-mentioned limits of these last two studies.

It is important to emphasize that no previous investigation has evaluated either cases of bilateral root exposures exclusively or such a large number of consecutive RECs per patient (mean of 6.55) as in the present study. In the previously mentioned clinical studies,<sup>7, 9, 14</sup> the number of consecutive RECs that underwent treatment varied with a mean of between 3.3 and 4.1 per patient. Even considering only the central incisors, the results of CAF with the tunneling procedure were better in terms of RECred and CRC than those of the control group were, although such a difference did not achieve statistical significance in this case. No comparison is possible with other investigations concerning specific data on these teeth, since the key role of this method in the symmetry and esthetics of the smile has not been reported in literature prior to this study.

### Conclusion

CAF performed with tunneling of the maxillary midline papilla can be considered a minimally invasive, safe and predictable surgical procedure, but failed to demonstrate significant additional benefits in terms of RECred and CRC compared with a conventional approach in this randomized clinical trial.

#### **Competing interests**

The authors declare that they have no competing interests. The study was self-funded by the authors.



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#### Coronally advanced flap in the treatment of bilateral multiple gingival recessions

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# Five-year esthetic evaluation of implants used to restore congenitally missing maxillary lateral incisors after orthodontic space opening treatment

#### Abstract

### Objective

This is a five-year follow-up study of a previous investigation with the aim of assessing the esthetic outcome of Morse taper implants used to replace congenitally missing lateral incisors after orthodontic treatment.

#### Materials and methods

Twenty consecutively treated patients were treated using Morse taper connection implants (Leone Implant System, Leone, Florence, Italy) after orthodontic space opening. The pink esthetic score/white esthetic score index was applied by an independent calibrated examiner to the implant-supported restorations at the five-year recall visit, comparing the esthetic outcome to the previous examinations performed at the three-month and the three-year recall visits.

#### Results

No implants were lost. All of the implants fulfilled the established success criteria for dental implants with regard to osseointegration and prosthetic complications, with an overall implant–crown success rate of 100%. At the five-year follow-up, the mean distance between the implant shoulder and the first visible bone–implant contact was  $0.44 \pm 0.14$  mm (95% CI: 0.41-0.47), the mean pink esthetic score was  $8.35 \pm 1.63$  and the mean white esthetic score was  $8.80 \pm 1.00$ .

### Conclusion

The use of single-tooth Morse taper connection implants for replacing congenitally missing maxillary lateral incisors after orthodontic treatment appears to be a successful procedure.

#### K e y w o r d s

Implants, congenitally missing lateral incisors, orthodontic space opening treatment.

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### Introduction

Dental agenesis is defined as the congenital absence of a tooth bud. It is a condition of unknown etiology, although some theories have been formulated.<sup>1</sup> Its incidence varies among races and sexes. Maxillary lateral incisors are the second most frequent tooth type, after the second premolars and excluding the third molars, affected by this condition.<sup>2</sup> The estimated rate of incidence of congenitally missing maxillary lateral incisors ranges from 5% to 8%.<sup>3</sup> Dental agenesis occurring in the esthetic area has a high impact on smile attractiveness, impairing the smile balance and harmony.<sup>4</sup> Therefore, it must be carefully addressed and requires a team approach.

Classically, congenitally missing lateral incisors can be restored in three ways.<sup>5</sup> A camouflage treatment modality can be performed by mesialization of the canine into the lateral incisor space and performing conservative reshaping of the canine to mimic the incisor.<sup>6</sup> A second treatment possibility is a space opening orthodontic approach, aiming to create adequate space for the placement of an osseointegrated implant in the incisal area or to allow the seating of a fixed partial denture.<sup>5</sup> The third option is orthodontic creation of space in the posterior area to allow the placement of an implant in the premolar area.<sup>7</sup>

Implant therapy is an established treatment modality for the rehabilitation of single or multiple missing teeth with high implant success rates in the long term.8 Dental implants are able to provide a high esthetic outcome in very demanding clinical situations, such as the rehabilitation of missing teeth in the premaxilla.<sup>9</sup> In the last few years, investigators have focused their efforts on determining a reliable method that is able to evaluate the esthetic outcome of an implantsupported restoration objectively.<sup>10</sup> In the late 1990s, Jemt introduced the papilla fill index for assessing the size of the interproximal gingiva.<sup>11</sup> Recently, Fürhauser et al. proposed an index called the pink esthetic score (PES) that evaluates different aspects of the soft tissue surrounding the implants.<sup>12</sup> Unfortunately, this method focuses only on the outcome of the periimplant tissue and does not consider the restoration. The final esthetic result of implant rehabilitation is the sum of many variables, including the soft tissue, and the restoration plays a pivotal role in the final result.<sup>13</sup> In 2009, Belser et al. introduced the pink esthetic score/white esthetic score (PES/WES), an index able to provide a comprehensive evaluation of the esthetic outcome of an implant-supported rehabilitation.<sup>14</sup> This index allows the clinician to assess either soft-tissue variables or variables related to the restoration itself. A value of 2, 1 or 0 is assigned to every parameter. An evaluation of all of the variables is performed by direct comparison with the natural contralateral reference tooth. Thus, a final score is assigned that estimates the final degree of match or mismatch.<sup>14</sup>

The aim of the present retrospective study is to evaluate the five-year esthetic outcome of a single crown supported by a Morse taper connection implant used to replace a congenitally missing maxillary lateral incisor after orthodontic treatment.

### Materials & methods

### Patient population

Twenty patients, 11 females and 9 males, with a mean age of 21.33 (range of 19.67–24.17) were identified from the patient chart and included in the study. They had been consecutively treated with Morse taper connection implants owing to congenitally missing maxillary lateral incisors after orthodontic space opening, from 2004 to 2009 at the dental clinic of the University of Insubria (Varese, Italy). Seven patients originally identified did not meet the inclusion criteria and were excluded.

#### The inclusion criteria were

- presence of natural teeth mesial and distal to the implant
- presence of the contralateral lateral incisor
- adequate bone height and width to place an implant of at least 3.3 mm in diameter and 10.0 mm in length.

The exclusion criteria were

- uncontrolled diabetes
- poor oral hygiene
- active periodontal infections
- bruxism
- smoking habit
- presence of a thin-scalloped gingival biotype.

The biotype was determined by the transparency of a periodontal probe through the gingival mar-



Fig.1

A lateral incisor at the baseline.



Fig. 2

The implant-supported restoration after five years.



gin while probing the buccal sulcus of the maxillary central incisor.<sup>15</sup> Patients who had undergone implant treatment with hard- or soft-tissue grafting before implant placement and periodontally compromised patients were excluded too. All of the patients read and signed a written consent form for immediate implant placement. The study protocol was conducted in accordance with the Declaration of Helsinki of 1975, as revised in 2007. The local ethics committee approved the study protocol.

#### Surgical and prosthetic procedure

A complete examination of the oral hard and soft tissue was carried out for each patient, and the implant placement was planned based on clinical and radiographic evaluation. Surgery was performed under local anesthesia, obtained by infiltrating 4% articaine containing 1:100,000 epinephrine (Ubistesin, 3M ESPE, St. Paul, Minn., U.S.). A mesiodistal crestal incision was made and a full-thickness flap was reflected, exposing the alveolar ridge. Preparation of implant sites was carried out with spiral drills of increasing diameter (2.8 mm to place an implant with a 3.3 mm diameter; 2.8 and 3.5 mm to place an implant with a 4.1 mm diameter; an additional 4.2 mm drill was used to prepare the site for an implant with a 4.8 mm diameter), under constant irrigation. Implants were positioned at the bone crest level. The implant system used in this study (Leone Implant System, Leone, Florence, Italy) is characterized by a cone Morse taperedinterference fit locking taper combined with an internal hexagon. The Morse taper has a taper angle of 1.5°.

Temporary abutments were placed and all of the patients received a temporary acrylic resin crown cemented with a temporary cement (TempBond, Kerr, Orange, Calif., U.S.). None of the temporary crowns were in full contact in centric occlusion. The flaps were properly mobilized and repositioned to cover the implants and were secured in position with interrupted sutures (Supramid,Novaxa, Milan, Italy). Figs. 3 & 4





#### Fig. 3

Radiographic control of the implant at the baseline.

#### Fig. 4

Radiographic control of the implant after five years.

All of the patients received oral antibiotics (Augmentin, GlaxoSmithKline, Brentford, UK; 2 g per day) for six days. Postoperative pain was controlled by administering 100 mg nimesulide (Aulin, Roche Pharmaceuticals, Basel, Switzerland) every 12 h for two days, and detailed instructions on oral hygiene were given, including mouth rinsing with 0.12% chlorhexidine (Chlorhexidine, Oral-B, Boston, Mass., U.S.) for seven days. Suture removal was performed at eight to ten days. The temporary restorations remained in situ for three months, and after this period definitive restorations were placed (Figs. 1-3). All of the single crowns were metal-ceramic and were cemented with a temporary cement (Temp-Bond).

### Clinical follow-up examination

Follow-up visits were scheduled at two weeks, as well as one, three and 12 months, during the first year postoperatively and at 24, 36 and 60 months postoperatively. Five years after implant

placement, the following clinical and radiographic parameters were assessed at the recall visit: (a) presence/absence of pain or suppuration; (b) presence/absence of clinically detectable implant mobility; (c) presence/absence of prosthetic complications at the implant-abutment interface; (d) presence/absence of periimplant radiolucency; and (e) distance between the implant shoulder and the first visible bone-implant contact (DIB). Periapical radiographs were taken at the baseline (immediately after implant placement) and at the yearly scheduled follow-up session.<sup>16</sup> Radiographs were taken using a Rinn alignment system (DENTSPLY RINN, Elgin, Ill., U.S.) with a rigid film-object X-ray source coupled to a beam-aiming device to achieve reproducible exposure geometry. Customized positioners made of polyvinyl siloxane were used for precise repositioning and stabilization of the radiographic template.

In order to calculate the DIB, changes in the crestal bone level were recorded as changes in the vertical dimension of the bone around the
## Table 1

Detailed PES values for all 20 restorations at the baseline.

Patient	Mesial papilla	Distal papilla	Curvature of facial mucosa	Level of facial mucosa	Root convexity; soft-tissue color and texture	Total PES
1	1	2	2	2	2	9
2	2	2	2	2	2	10
3	1	2	2	2	2	9
4	2	1	1	1	1	6
5	1	1	2	2	1	7
6	1	1	1	1	1	5
7	2	1	1	2	2	8
8	2	2	1	2	2	9
9	2	2	1	2	2	9
10	2	2	2	2	2	10
11	2	2	1	2	1	8
12	2	2	2	2	1	9
13	2	2	1	1	2	8
14	2	1	1	1	1	6
15	1	2	1	2	1	7
16	1	2	2	1	2	8
17	2	2	2	2	2	10
18	2	1	2	1	1	7
19	1	1	2	2	2	8
20	1	2	2	1	1	7
Mean	1.60	1.65	1.55	1.65	1.55	8.00

#### Table 2

Detailed PES values for all 20 restorations at the three-year follow-up.

Patient	Mesial papilla	Distal papilla	Curvature of facial mucosa	Level of facial mucosa	Root convexity; soft-tissue color and texture	Total PES
1	2	2	2	2	2	10
2	2	2	2	2	2	10
3	1	2	2	2	2	9
4	2	2	1	1	1	7
5	1	1	2	2	1	7
6	1	1	1	1	0	4
7	2	1	1	2	2	8
8	2	2	1	2	2	9
9	2	2	2	2	2	10
10	2	2	2	2	2	10
11	2	2	1	2	1	8
12	2	2	2	2	1	9
13	2	2	1	2	2	9
14	2	1	1	1	1	6
15	1	2	1	2	1	7
16	1	2	2	1	2	8
17	2	2	2	2	2	10
18	2	1	2	1	1	7
19	1	1	2	2	2	8
20	1	2	2	1	0	6
Mean	1.65	1.70	1.60	1.70	1.45	8.15

Patient	Mesial papilla	Distal papilla	Curvature of facial mucosa	Level of facial mucosa	Root convexity; soft-tissue color and texture	Total PES
1	2	2	2	2	2	10
2	2	2	2	2	2	10
3	2	2	2	2	2	10
4	2	2	1	1	1	7
5	2	1	2	2	1	8
6	1	1	1	1	0	4
7	2	2	1	2	2	9
8	2	2	1	2	2	9
9	2	2	2	2	2	10
10	2	2	2	2	2	10
11	2	2	1	2	1	8
12	2	2	2	2	1	9
13	2	2	1	2	2	9
14	2	2	1	1	1	7
15	1	2	1	2	1	7
16	2	2	2	1	2	9
17	2	2	2	2	2	10
18	2	1	2	1	1	7
19	1	1	2	2	2	8
20	1	2	2	1	0	6
Mean	1.80	1.80	1.60	1.70	1.45	8.35

## Table 3

Detailed PES values for all 20 restorations at the five-year follow-up.

Patient	Tooth form	Tooth volume	Tooth color	Surface texture	Translucency	Total WES
1	2	2	2	1	1	8
2	2	2	2	2	1	9
3	2	2	2	1	1	8
4	2	1	1	2	2	8
5	1	2	2	2	2	9
6	1	2	2	2	2	9
7	1	2	2	2	2	9
8	2	2	1	2	1	8
9	2	1	2	2	2	9
10	2	2	2	2	2	10
11	2	1	1	1	1	6
12	1	2	1	2	1	7
13	1	2	2	1	2	8
14	2	2	2	2	2	10
15	2	1	2	2	1	8
16	2	1	1	2	2	8
17	1	1	1	2	2	7
18	2	1	1	2	1	7
19	2	2	1	1	0	6
20	2	2	2	2	2	10
Mean	1.70	1.65	1.60	1.75	1.50	8.15

# Table 4

Detailed WES values for all 20 restorations at the baseline.

## Table 5

Detailed WES values for all 20 restorations at the three-year follow-up.

Patient	Tooth form	Tooth volume	Tooth color	Surface texture	Translucency	Total WES
1	2	2	2	1	2	9
2	2	2	1	2	2	9
3	2	1	2	1	1	7
4	2	1	1	2	2	8
5	1	2	2	2	2	9
6	1	2	2	2	2	9
7	1	2	2	2	1	8
8	2	2	2	2	2	10
9	2	1	2	2	2	9
10	2	2	2	2	1	9
11	2	2	2	2	2	10
12	1	2	1	2	1	7
13	2	2	1	2	2	9
14	2	2	2	2	2	10
15	2	1	2	2	1	8
16	2	1	1	2	2	8
17	2	1	2	2	2	9
18	2	2	1	2	1	8
19	2	2	2	1	1	8
20	2	2	2	2	2	10
Mean	1.80	1.70	1.70	1.85	1.65	8.70

#### Table 6

Detailed WES values for all 20 restorations at the five-year follow-up.

Patient	Tooth form	Tooth volume	Tooth color	Surface texture	Translucency	Total WES
1	2	2	2	1	2	9
2	2	2	2	2	2	10
3	2	1	2	1	1	7
4	2	1	1	2	2	8
5	1	2	2	2	2	9
6	2	2	2	2	2	10
7	1	2	2	2	1	8
8	2	2	2	2	2	10
9	2	1	2	2	2	9
10	2	2	2	2	1	9
11	2	2	2	2	2	10
12	1	2	1	2	1	7
13	2	2	1	2	2	9
14	2	2	2	2	2	10
15	2	1	2	2	1	8
16	2	1	1	2	2	8
17	2	1	2	2	2	9
18	2	2	1	2	1	8
19	2	2	2	1	1	8
20	2	2	2	2	2	10
Mean	1.85	1.70	1.75	1.85	1.65	8.80

implant, so that an evaluation of periimplant crestal bone stability was gained with time. In order to correct for dimensional distortion in the radiograph, the apparent dimension of each implant (directly measured on the radiograph) was compared with the true implant length, in order to establish with adequate precision the eventual amount of vertical bone loss at the mesial and distal sites of the implant. The DIB was calculated by means of an ocular grid. The established criteria for implant-crown success were as follows: (a) absence of pain or suppuration; (b) absence of clinically detectable implant mobility; (c) absence of periimplant radiolucency; (d) a DIB of < 1.5 mm after 12 months of functional loading and of  $\leq 0.2$  mm for each following year;<sup>17</sup> and (e) absence of prosthetic complications at the implant-abutment interface.

### Esthetic follow-up examination

In order to examine the esthetic outcome of the implants objectively, intra-oral photographs were critically analyzed using the PES/WES index.<sup>14</sup> All of the implant crowns were photographed with a digital camera (Nikon D100, Nikon, Tokyo, Japan) and a 105 mm lens (AF Micro Nikkor 105 mm 1:2.8 D, Nikon) with a ring flash (Nikon SB-29S Macro Speedlight, Nikon). For assessing anterior tooth replacements, the reference contralateral tooth had to be completely and symmetrically represented in order to ensure comparability. For this purpose, the photographs were centered at the midline, in order to facilitate the subsequent analysis, which was primarily based on symmetry. In addition, standardized clinical photographs were taken of each implant site and of the contralateral tooth (Figs. 2-4). These additional photographs were used as tools for a more detailed evaluation. All of the photographs were taken slightly superior to the occlusal plane, centered at the contact region. Photographs were then viewed on a 42 in. monitor (PPM42S3Q Plasma Display Panel Monitor, Samsung, Seoul, South Korea). Study casts, produced in Type IV stone, were finally fabricated for each of the 20 patients involved in the study. Study casts were fabricated to facilitate a direct and objective assessment related to the PES/WES index.

The clinical photographs and the study casts were used to perform the esthetic evaluation. The esthetic evaluation was performed by an independent calibrated observer who was not

part of the treating team, by means of the PES/ WES index 1 h after seating of the definitive restoration (three months after implant placement), and three years and five years after implant placement (follow-up), respectively.<sup>18</sup> In order to reduce bias and to achieve good reproducibility, the evaluation was carried out twice, on different days. In the case of diverging scores, the observer carefully re-evaluated the photographs and the study casts prior to making his final decision. A score of 2, 1 or 0 was assigned to each PES/WES parameter. The highest possible PES score was 10, which represented a close match of the periimplant soft-tissue conditions, and the highest possible WES score was 10, representing a close match of the clinical single-tooth crown compared with the respective features of the natural contralateral tooth.

#### Data analysis

For the PES and WES evaluation, descriptive statistics, including mean values, standard deviations, medians and range, were analyzed. Moreover, in order to compare the differences in PES and WES assessments between the baseline and follow-up, the Wilcoxon rank-sum test for paired data was performed. The level of significance was set at 0.05. All statistical analyses were run on the SPSS statistical package (Version 17.0; SPSS, Chicago, Ill., U.S.).

#### Results

Data from 20 patients were examined, with a mean time from surgery to evaluation of five years. No implants were lost. With regard to osseointegration, all 20 anterior maxillary single-tooth implants fulfilled the success criteria, with an implant–crown success rate of 100%. All of the implants showed stable osseointegration, with absence of pain or suppuration, absence of clinically detectable implant mobility, absence of periimplant radiolucency, a DIB of < 1.5 mm during the first year of function, and absence of prosthetic complications at the implant–abutment interface. The mean DIB was 0.44  $\pm$  0.14 mm (95% CI:0.41–0.47) at the five-year follow-up.

The five-year PES/WES values are shown in **Tables 1–6**. The mean PES was  $8.35 \pm 1.63$ . With respect to the PES index, there was a significant

improvement compared with the baseline and the three-year follow-up (p < 0.05). Six implants scored a perfect PES value at the five-year evaluation, eight of the remainder had a PES of  $\geq$  8 and only one implant showed an overall PES of < 6. The mean WES was 8.8 ± 1.0. With respect to the WES index, there were no significant differences compared with the baseline and the three-year follow-up (p < 0.05).

## Discussion

Implant therapy is a successful procedure in many clinical scenarios and nowadays is a reliable and predictable treatment modality. A number of scientific trials have proved that implants have a high survival rate in the long term.<sup>8, 19, 20</sup> Many investigators have focused on the esthetic outcome of implants in the esthetic area using different loading protocols, but the literature is scarce on objective evaluation of the esthetic results of implants used to rehabilitate congenitally missing lateral incisors.<sup>21</sup>

The survival rates of implants used to restore maxillary lateral incisors are very high, thus offering both the clinician and the patient high reliability in terms of clinical success.<sup>13, 22</sup> Our data demonstrated a 100% implant-crown success rate, showing no implant failure. Furthermore, a stable bone level was observed throughout the observation period. This is a crucial aspect for maintaining long-term function and for achieving an excellent esthetic outcome. Morse taper connection implants have been proved to yield high functional performance owing to the implant-abutment connection stability. When a prosthetic abutment is connected to a fixture, a microgap is created between the components. Microorganisms may grow into this microgap and establish a bacterial reservoir, resulting in an area of inflamed soft tissue facing the implant-abutment interface. The presence of this microgap may thus have a role in the development of periimplant inflammation and bone loss, as demonstrated by previous studies.<sup>23, 24</sup> Our data demonstrated a high PES value of 8.35 ± 1.63, showing significant differences compared with the baseline and the three-year follow-up. Moreover, there were no changes to the mesial and the distal papillae, and the level of the facial mucosa remained stable, showing no recession. For an optimal esthetic result, it is mandatory to preserve the level of the marginal bone around the implant.<sup>21</sup> The main factors hypothe-

sized to be responsible for marginal bone loss include surgical trauma, micromovements of the abutment, the formation of biologic width, and the presence and size of a microgap between the implant and the abutment. It is known that when an abutment is connected to an implant bone loss always occurs.<sup>25</sup> The features of the implant-abutment connection are considered to influence both the mechanics and the biological behavior of implants.<sup>26</sup> The presence of a microgap at the implant-abutment connection may have a direct effect on bone loss.<sup>27</sup> In implants with screw-retained abutments, this microgap can vary in dimension from 40 µm to 100 µm and can be potentially colonized by bacteria, thus generating a chemotactic stimulus sustaining the recruitment of inflammatory cells, and ultimately resulting in inflammation and osteolysis.27

The Morse taper connection is able to avoid micromovements, removing de facto one of the reasons for crestal bone resorption. This connection system gives all the advantages of a platform switching design, achieving a horizontal repositioning of the microgap and more space for the establishment of connective tissue; both of these factors play an important role in the maintenance of a biological seal against bacteria that can impair the marginal bone stability.<sup>28</sup> With regard to the WES index, no differences were observed in the present study. After five years of function, the mean DIB was 0.44 ± 0.14 mm, demonstrating that this particular kind of implant connection system is able to guarantee bone stability in the long term, as demonstrated by previous studies.<sup>16, 29</sup>

#### Conclusion

Within the limits of this study, the use of single-tooth Morse taper connection implants for the restoration of congenitally missing maxillary lateral incisors after orthodontic treatment appears to be a successful procedure, demonstrating (*a*) a high PES value, (*b*) a high esthetic outcome in the long-term and (*c*) a high implant– crown success rate.

#### **Competing interests**

The authors declare that they have no competing interests related to this study. No financial support was received for this study.

#### Esthetic evaluation of implants after orthodontic space opening treatment

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